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Innovation Sticks: The Limited Case for Penalizing Failures to Innovate

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When policymakers and academics think about designing optimal innovation incentives, they almost exclusively limit their considerations to various types of reward incentives—that is, innovation "carrots." But in this Article, we show that, under specific circumstances, innovation "sticks"—potential penalties for failures to innovate—can play valuable roles in our innovation policy, either alone or in conjunction with innovation carrots. We also provide examples of several innovation sticks that have already been used with apparent success, including the federal Corporate Average Fuel Economy standards. Finally, we apply our approach to a new area—the problem of car fatalities—to illustrate the potential of innovation sticks to yield substantial social benefits. Our model suggests that a relatively simple system of yardstick penalties could help reduce national auto fatalities by as much as 20 percent simply by bringing laggard entities (such as companies and states) up to the median.

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INTRODUCTION

It has long been said that necessity is the mother of invention.[1] You would not know it from reading today's innovation literature, though. That literature focuses almost exclusively on "carrots," or opportunities for rewards. The most important such rewards discussed in the legal literature are intellectual property rights (IPRs), which give creators the privilege of excluding others from the marketplace.[2] Financial inducement prizes and government grants have also been widely discussed, particularly in the economics literature.[3] Recent attention has also been given to additional mechanisms such as R & D tax credits[4] and "commons-based" approaches.[5]

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1 The phrase goes back, in fact, to Plato. See Plato, *The Republic*, in 3 *The Dialogues of Plato* 1, 49 (Oxford 3d ed 1931) (B. Jowett, trans).

2 See, for example, Robert P. Merges, *Justifying Intellectual Property* 27 (Harvard 2011); William M. Landes and Richard A. Posner, *The Economic Structure of Intellectual Property Law* 111 (Harvard 2003).

3 See Suzanne Scotchmer, *Innovation and Incentives* 31–58 (MIT 2006); Brian D. Wright, *The Economics of Invention Incentives: Patents, Prizes, and Research Contracts*, 73 Am Econ Rev 691, 703–04 (1983).

4 See, for example, Daniel J. Hemel and Lisa Larrimore Ouellette, *Beyond the Patents–Prizes Debate*, 92 Tex L Rev 303, 321–26 (2013) (focusing on R & D tax incentives); Shaun P. Mahaffy, Note, *The Case for Tax: A Comparative Approach to Innovation Policy*, 123 Yale L J 812, 843–44 (2013) (discussing the use of the tax system to bolster research incentives).

5 Yochai Benkler, *The Wealth of Networks: How Social Production Transforms Markets and Freedom* 320–55 (Yale 2006).

This vast literature, however, presents a puzzle: it does not address what role, if any, "sticks" might play in innovation policy.[6] This Article introduces the concept of the innovation sticks as a policy tool and describes their advantages and limits. Instead of rewarding an actor for innovating, innovation sticks threaten to penalize an actor for failing to innovate. Drawing on the insights of the new carrots-and-sticks literature, we describe why innovation sticks have been invisible in the intellectual property (IP) field and theorize the circumstances in which sticks may be a good policy choice, either alone or—likely more often—in conjunction with traditional or nontraditional carrots.

Because they provide penalties rather than rewards, innovation sticks cannot perform one function that is often assumed essential in the IP and information-economics literature: they cannot compensate parties for their investments in information production.[7] This literature thus suggests that innovation sticks should not exist. Yet they do.

The federal government's Corporate Average Fuel Economy (CAFE) standards, for example, create penalties for car companies whose fleets fail to meet fuel-efficiency standards that increase over time.[8] The CAFE program is a stick because it mobilizes penalties rather than rewards, and in our parlance it is an "innovation" stick because it plausibly induces innovation or the

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6 The only work we are aware of that identifies the potential of innovation sticks is a recent unpublished working paper. See generally Julien Pénin, *Should We Oblige Firms to Invest in R&D? Knowledge Spillovers and the Market of "Not to Invest in R&D Tradable Permits"* (unpublished manuscript, Nov 14, 2013), archived at http://perma.cc/NZ9H-J9V8. In that paper, Professor Julien Pénin makes the case for one particular kind of stick—a system of tradable permits not to engage in R & D—rather than a case for sticks in general. We come to some similar conclusions, particularly regarding the possible promise of sticks, but we develop a set of arguments—for example, about the innovation literature, the undercompensation problem, and the possible trade-offs between nontraditional carrots and sticks—that he does not. Professor Jay P. Kesan talks about adopting carrot-and-stick incentives within the patent system to produce better prior art disclosures, but he does not consider penalizing failures to innovate. See generally Jay P. Kesan, *Carrots and Sticks to Create a Better Patent System*, 17 Berkeley Tech L J 763 (2002).

7 As Professors Gerrit De Geest and Giuseppe Dari-Mattiacci put it, "Stick regimes naturally undercompensate and therefore also tend to violate the participation constraints of agents. Carrots, on the other hand, are either fully compensatory or overcompensatory." Gerrit De Geest and Giuseppe Dari-Mattiacci, *Carrots versus Sticks* *18 (Washington University in St. Louis School of Law Legal Studies Research Paper Series, Aug 2009), archived at http://perma.cc/4LGX-SGKH. For a description of why the compensation of innovators is typically assumed necessary, see Part I.B.

8 For a fuller description of the CAFE standards, see Part II.A.

production of new information.[9] Although there is disagreement about the efficacy of the CAFE program, a National Research Council review in 2002, for example, concluded that "[t]he CAFE program has clearly contributed to increased fuel economy of the nation's light-duty vehicle fleet during the past 22 years."[10] CAFE standards are set by regulators who have long seen them as "technology forcing."[11] Recent amendments have pushed further to include standards that are "augural, meaning that they represent [the National Highway Traffic Safety Administration's] current best estimate, based on the information available to the agency today, of what levels of stringency might be maximum feasible in those model years."[12] The existing IP literature, however, gives us few tools for understanding why the program might exist, why it might be effective, or whether it is an example of a broader possible set of innovation tools.

Before proceeding, it is important to address whether there is a meaningful difference between carrots and sticks. As Professor Wendy Gordon has observed: "One can verbally transform most benefit questions into 'harms' and vice versa by juggling the baseline from which effects are measured."[13] If automobile manufacturers expected, as one of the costs of doing business, to pay the government $50 million per year for the environmental damage done by their cars, then any possibility of reducing the payment—say, to merely $40 million—might be experienced as a carrot. We readily acknowledge that whether something is seen as a carrot or a stick depends on the baseline framing, which can, in some instances, be malleable. Then again, it is the rare mousetrap manufacturer who views the failure of the government to grant a twenty-year monopoly on a new product as a punishment for not coming up with a better trap. And it is the rare automobile manufacturer who views a CAFE fine as the absence of a reward. As we emphasize below,[14] potential inventors

9 We return to the question of what we mean by "innovation" in Part I.B.

10 National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* 3 (National Academy 2002) ("CAFE Report").

11 *Center for Auto Safety v National Highway Traffic Safety Administration*, 793 F2d 1322, 1339 (DC Cir 1986).

12 Environmental Protection Agency and Department of Transportation, 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 77 Fed Reg 62624, 62627 (2012).

13 Wendy J. Gordon, *Of Harms and Benefits: Torts, Restitution, and Intellectual Property*, 21 J Legal Stud 449, 451 (1992).

14 See Part I.A.

volunteer for carrots—for example, when they apply for a patent. Potential inventors who ultimately fail are unlikely to self-nominate to bear the pain of the stick.[15]

In Part I, we set forth our theoretical account of the potential and limits of innovation sticks. We begin by briefly reviewing the justifications offered for IP, as well as the main trade-offs identified in the IP and innovation-economics literature among different kinds of carrots, and in particular between what we will call "traditional carrots" (namely, exclusion rights), and "nontraditional carrots" (most prominently, government grants and prizes). Certain benefits and drawbacks of each of these mechanisms have long been identified in the literature. For example, a key trade-off between prizes and patents is in the comparative costs (including of error) of government estimations of the values of the desired innovations versus the comparative costs of the deadweight losses associated with exclusive rights.[16]

We also recount several more-recent arguments for the importance of nontraditional carrots, stressing these because they also expand the potential utility of sticks. In particular, nontraditional carrots—and nontraditional sticks (together, "nontraditional measures")—are particularly useful when predictable market failures exist.[17] For example, markets radically undervalue pollution-saving endeavors from a social perspective, helping to explain the existence of CAFE standards.[18] CAFE gains cannot be induced through market measures (absent a significant market-correcting initiative, such as a carbon tax, that, however sensible, is widely considered infeasible).[19] In addition, nontraditional measures are especially useful to create incentives for actors, such as states, that are not significantly incentivized by market-based innovation rewards.

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15 For those hard-core advocates of the view that every stick can be redescribed as a carrot (and vice versa), our argument is that policymakers should be more willing to move the baseline—as in our car-fatality example, by changing the default to a large tax that can be reduced (a carrot) only if the manufacturer exceeds the median rate of safety.

16 See Part I.A.

17 See Part I.C.

18 See Mark R. Jacobsen, *Evaluating US Fuel Economy Standards in a Model with Producer and Household Heterogeneity*, 5 Am Econ J: Econ Pol 148, 173–74 (2013) (noting that CAFE regulation seeks to reduce gasoline consumption, which is associated with external environmental and geopolitical costs).

19 See, for example, Eduardo Porter, *Taxes Show One Way to Save Fuel* (NY Times, Sept 11, 2012), archived at http://perma.cc/DT95-27CG (noting the recent failure of President Barack Obama's carbon-allowances measure).

We also stress another point, this one less familiar: innovation is often multimodal—for example, it may occur via technical change or via "social innovation" (which may be organizational, political, or related to the formation of new preferences or ways of living).[20] When we are uncertain which mode of innovation is needed (or cheapest), innovation-promoting tools that are themselves *agnostic as to the mode of innovation* may be desirable. We may even want tools that can be agnostic as to whether achievement comes through innovation or through the uptake of existing innovations. Sticks and nontraditional carrots have this quality, while traditional exclusion rights do not.

Importantly, nontraditional measures also have significant shared drawbacks. Most prominently, to be effective, they impose distinctive informational demands on the government—including, for example, defining the trigger for awarding the carrot or imposing the stick. Because of the importance of this problem, we stress one possible strategy to minimize this informational burden, drawing from the economics literature on "yardstick competition."[21]

Up to this point, we have discussed features of an innovation environment that should lead one to consider nontraditional measures to promote innovation. But a question remains: When should these be carrots, and when sticks? Part I closes by setting out some of the theoretical benefits and drawbacks of innovation sticks as compared to nontraditional carrots. One key benefit of sticks is that, in equilibrium, they may not need to be paid. In contrast to the distortions associated with either patent pricing or the generation of tax revenue for prizes, the threat of penalties for failures to innovate may produce equilibria with fewer price distortions. Put simply, if a government has a choice between a threat or a payment to induce innovation, ceteris paribus, the threat will be cheaper. Both will induce parties to expend resources to innovate, but the payment will also require the government to raise resources for the reward and so will trigger the distortions associated with taxation. Relatedly, when the threat of a stick works to produce innovation, innovators are not compensated for their efforts. This undercompensation of

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[20] See notes 91–92.

[21] See, for example, Andrei Shleifer, *A Theory of Yardstick Competition*, 16 Rand J Econ 319, 319–20 (1985) (defining "yardstick competition" as the comparison of "similar regulated firms with each other," which allows the regulator to "infer a firm's attainable cost level").

innovative efforts in the long run may lead innovators to exit from an industry, which may or may not be a problem. When sticks are targeted at externalities, they can have salutary effects even if they reduce activity levels—for example, if cars whose benefits do not exceed their costs to third parties are eliminated from the market, this is a social gain, not a loss.

Sometimes, though, we will not want to induce exit as a penalty for failing to innovate, making the undercompensation issue more acute. We therefore offer several reasons to think that the undercompensation problem is less extensive than the conventional literature suggests, and here, too, we draw on the insight that innovation is often multimodal. We suggest that the most important factor in choosing between a stick and a nontraditional carrot is the comparative risk of undercompensation versus overcompensation. We also identify several other relevant considerations, such as the possibilities that sticks impose different informational burdens on the government than do carrots, that sticks may be difficult for the government to credibly deploy, and that sticks may have adverse distributional consequences. Sticks also share risks with nontraditional carrots, such as the risk that parties will game the criteria for success, and these too must be taken into account. Traditional carrots, of course, have well-known drawbacks as well (including their own forms of gaming and rent-seeking[22]), so the ultimate analysis will be a comparative one. Importantly, though, we should not think of the choice as either-or. Innovation sticks can readily be combined with traditional and nontraditional carrots, and we suggest below some benefits and risks of a combined approach.

In Part II, we describe several real-world examples of innovation sticks to make our theoretical analysis more accessible.[23] As with CAFE, several of our examples target private actors. But we also provide examples, such as portions of the No Child Left Behind Act of 2001[24] (NCLB), in which government actors have been challenged to improve or else face financial and nonfinancial penalties. Some of our examples at least indirectly deploy yardsticks in that the penalty trigger is derived in part

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22 See, for example, Landes and Posner, *The Economic Structure of Intellectual Property Law* at 220 (cited in note 2).

23 In the Appendix, we also describe several more examples: two drawn from the environmental context, one related to tobacco control, and one addressing the use of tort liability as an innovation stick. The Appendix is available online at http://lawreview.uchicago.edu/page/ayres-kapczynski or from the authors on request.

24 Pub L No 107-110, 115 Stat 1425.

from what other actors have achieved or will be able to achieve. Our theory helps us understand why sticks may have been used in the cases we identify, and it also suggests that many of these innovation sticks might be more successful if they were more directly tied to yardstick competition to help determine who is penalized and how large the penalty will be. We also point out how broadly the category of sticks can be conceived. Cap-and-trade systems like the Chicago Climate Exchange—in which more than 350 firms agreed to greenhouse-emission caps that reduce emissions by 1 percent per year—combine carrot and stick incentives in the selling and buying of rights to innovate to save energy.[25] Even simple prohibitions, such as laws that ban incandescent lightbulbs or chlorofluorocarbons (CFCs), can be a powerful impetus for innovation.[26]

The image of the lightbulb going on has been a longstanding visual metaphor for the moment of creativity. Our analysis suggests a twist on this conventional image: some innovations are not about a lightbulb turning *on*, but about a lightbulb turning *off*. When the Energy Independence and Security Act of 2007[27] ordained that manufacturers would need to cease manufacturing most incandescent lightbulbs by 2014, industry participants had strong incentives to create alternative sources for lighting.[28]

Seen this way, the concept of innovation sticks is very broad indeed. After all, every fine and prohibition might lead to innovation, because innovation can permit actors to avoid or lessen the impact of the penalty.[29] The law against homicide, we might say, does not just prohibit homicide. It also creates incentives for people to harm others in legal ways or to develop forms of homicide

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25 See Ian Ayres and Barry Nalebuff, *Your Personal Climate Exchange* (Forbes, Nov 7, 2008), archived at http://perma.cc/P89Y-328X; Ian Ayres, *Carrots and Sticks: Unlock the Power of Incentives to Get Things Done* 138 (Bantam 2010).

26 See Leora Broydo Vestel, *Incandescent Bulbs Return to the Cutting Edge* (NY Times, July 5, 2009), archived at http://perma.cc/B72Z-FHHH; René Kemp, et al, *Policy Instruments to Stimulate Cleaner Technologies*, in J.B. Opschoor and R.K. Turner, eds, *Economics Incentives and Environmental Policies: Principles and Practice* 275, 289 (Kluwer Academic 1994) (explaining that the general ban on CFCs can be considered a technology-forcing standard that is strong enough to incentivize CFC-substituting innovations).

27 Pub L No 110-140, 121 Stat 1492.

28 See Vestel, *Incandescent Bulbs Return to the Cutting Edge* (cited in note 26) ("[T]he incandescent bulb is turning into a case study of the way government mandates can spur innovation.").

29 For example, the threat of liability for patent infringement can be seen as an innovation stick that incentivizes competitors to innovate around the patent.

that avoid detection. We are not convinced that the expansiveness of our concept of innovation sticks is a problem for our account. Interesting insights might come from thinking about parking bans and tax systems as sticks that—inadvertently—lead to innovation. Our primary interest, however, is not in investigating the far reaches of the concept but rather in facilitating our ability to think systematically through the virtues and costs of using innovation sticks to induce productive kinds of innovation.

In Part III, we offer an example of a yardstick stick mechanism that addresses the significant problem of automobile fatalities in the United States and that we think fairly shows both the enormous potential and the difficult design issues associated with ambitious carrot and stick (and indeed, yardstick) approaches to innovation. We show that identifiable manufacturers and states persistently lag behind the safety levels attained by their peers. For example, we find that just reducing the automobile-fatality rate in persistently above-median states would reduce national automobile fatalities by 20 percent, with an annual social benefit of more than $60 billion. Under one thought experiment, CAFE-like penalties would be visited on actors who failed to keep up with what the median actor had shown was feasible; these penalties would be transferred to reward below-median actors who pioneered safety improvements. Neither our empiricism nor our CAFE-like fatality proposal is intended to be definitive. But it is intended to further the plausibility of innovation sticks as a powerful policy tool that deserves to be included in policymaking processes.

We do not claim to have exhausted the possible benefits and drawbacks of innovation sticks, but we instead offer a preliminary analysis that shows that innovation sticks deserve—and indeed, already have—a place in the policymaker's tool kit. We also highlight key considerations that may make them advisable or inadvisable in particular circumstances. Often the question will be whether innovation sticks should be used in tandem with traditional and nontraditional carrots, so that we should consider whether using both carrots and sticks is preferable to relying merely on carrots.

I. The Case for Sticks

Mapping out the advantages and disadvantages of sticks requires us to first understand some of the limits of traditional innovation carrots and the possible benefits and drawbacks of nontraditional carrots, because sticks and nontraditional carrots have important similarities. After a brief, synthetic review of the key costs and benefits of traditional and nontraditional carrots, we define innovation sticks, describe possible implementations of sticks, and theorize some of their important advantages and disadvantages. We conclude this Part by drawing out the characteristics of an innovation environment that may lead us to prefer nontraditional measures over traditional carrots and that may lead us to choose sticks over nontraditional carrots or to combine sticks with carrots. Our aim here is not to be fully comprehensive of all possible arguments in favor of or against these various mechanisms but rather to highlight the main concerns made salient either by the literature or by our own examples.

A. The Role of Nontraditional Innovation Carrots

The existing innovation-economics and IP literature typically begins with something like the following account:[30] information is a public good; as such, it is both nonrivalrous and nonexcludable, and it is difficult to produce in competitive markets absent some form of government intervention. IPRs are such an intervention: they make information more excludable and so facilitate the production of information goods in private markets. There are other approaches to producing public goods, most prominently government grants, in which governments identify potential innovators and fund their research work ex ante, and financial inducement prizes, in which governments offer a financial reward ex post in exchange for an innovation that, in the classic model, is freely disseminated.[31] Both approaches are examples of what we call "nontraditional carrots."

The existing literature thus has focused on various forms of carrots—or incentives to innovators—and in particular on the trade-offs associated with the use of one kind of carrot or another. Both government grants and financial inducement prizes, in

[30] For leading accounts of this sort, which of course differ somewhat in their emphases and details, see Landes and Posner, *The Economic Structure of Intellectual Property Law* at 13–15, 21–24 (cited in note 2); Peter S. Menell and Suzanne Scotchmer, *Intellectual Property Law*, in A. Mitchell Polinsky and Steven Shavell, eds, 2 *Handbook of Law and Economics* 1471, 1476–82 (Elsevier 2007); Robert P. Merges, Peter S. Menell, and Mark A. Lemley, *Intellectual Property in the New Technological Age* 14 (Wolters Kluwer 5th ed 2010). For an influential article tracing the value of IPRs to the ability of markets to aggregate information, see Harold Demsetz, *Information and Efficiency: Another Viewpoint*, 12 J L & Econ 1, 11–14 (1969).

[31] See Hemel and Ouellette, 92 Tex L Rev at 317–21 (cited in note 4).

their ideal forms, require free access to the resulting innovations and so yield information that is priced at marginal cost (that is, at zero).[32] As such, they take advantage of the nonrivalrous nature of information and avoid the efficiency problems associated with pricing information. Given the inevitability of positive transaction costs and the impossibility of perfect price discrimination, IPRs are expected to insert "a wedge between price and marginal cost, creating deadweight loss."[33] This disparity leads to not only static but also dynamic inefficiencies, because information is an input and output of its own production process.[34] Nontraditional carrots require taxation and so are also expected to create deadweight loss.[35] But IPRs create the equivalent of a tax on a single market, "which is generally thought to impose greater deadweight loss than the broad-based taxation that generates general revenue."[36] It is for this reason that Professor Kenneth Arrow long ago insisted that nontraditional carrots are likely superior to traditional (exclusion-based) carrots as a general matter.[37]

Since Arrow's foundational work, economists have developed a more refined account of the trade-offs between traditional and nontraditional carrots. While doing some violence to a very complex literature, we can identify a few central trade-offs that are now fairly well understood.[38] The main benefit of IPRs is that they rely on market signals to allocate investment; in particular,

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32 See Amy Kapczynski, *The Cost of Price: Why and How to Get beyond Intellectual Property Internalism*, 59 UCLA L Rev 970, 981 (2012) ("[I]nformation only needs to be produced once for many people to enjoy it; in other words, its marginal cost of production is zero.").

33 Landes and Posner, *The Economic Structure of Intellectual Property Law* at 22 (cited in note 2).

34 See, for example, Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, 5 J Econ Persp 29, 31 (1991); Benkler, *The Wealth of Networks* at 37–38 (cited in note 5).

35 See Kapczynski, 59 UCLA L Rev at 986–87 (cited in note 32).

36 Nancy Gallini and Suzanne Scotchmer, *Intellectual Property: When Is It the Best Incentive System?*, in Adam B. Jaffe, Josh Lerner, and Scott Stern, eds, 2 *Innovation Policy and the Economy* 51, 54 (MIT 2002). See also Ian Ayres and Paul Klemperer, *Limiting Patentees' Market Power without Reducing Innovation Incentives: The Perverse Benefits of Uncertainty and Non-injunctive Remedies*, 97 Mich L Rev 985, 991–92 (1999).

37 See Kenneth J. Arrow, *Economic Welfare and the Allocation of Resources for Invention*, in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity: Economic and Social Factors* 609, 623 (Princeton 1962) (noting the importance of nonpecuniary incentives).

38 For a somewhat more detailed overview, see generally Kapczynski, 59 UCLA L Rev 970 (cited in note 32).

they allow markets to establish the value of innovations.[39] Inducement prizes require governments to establish the value of the innovations that they seek, but, like IPRs, they can be designed to incentivize decentralized efforts among innovators who are assumed to have advantages in calculating their costs of innovation.[40] Government grants, in turn, have special benefits when racing is expected to be a concern, because the government can limit the number of entrants.[41] Among their important drawbacks, grants not only require the government to establish the size of the reward but also require it to decide ex ante who are likely to be the most successful innovators.[42] Both kinds of nontraditional carrots are often described as having an additional important drawback—namely, their susceptibility to rent-seeking and corruption.[43]

A newer literature has begun to point out some additional potential benefits of nontraditional carrots, ones that were earlier overlooked. One benefit stems from the fact that excludability—the hallmark of IPRs—in fact exists on a continuum and is not a simple function of legal status.[44] An innovator who holds a legal entitlement to exclude others may in practice be unable or only weakly able to exclude others. Consider here the difference between excluding others from a new prescription diet drug in an environment in which medicines are highly regulated commodities and excluding others from using a new exercise regime that one has invented and validated.[45] Exclusion, in fact, is not a function merely of law but also of norms, technologies, and institutions. Importantly, some kinds of information goods are likely

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39 See id at 982–83. For some, this creates distributive benefits because those who want innovations pay for them. See, for example, Gallini and Scotchmer, *Intellectual Property* at 55 (cited in note 36). The distributive justice effects of innovation policy, however, are much more complex than this point would suggest. See Kapczynski, 59 UCLA L Rev at 1005 & n 132 (cited in note 32).

40 See Wright, 73 Am Econ Rev at 695 (cited in note 3).

41 See Kapczynski, 59 UCLA L Rev at 985 (cited in note 32) (summarizing the literature showing that racing among firms to obtain a patent reward can lead to inefficient entry decisions and social waste).

42 See Wright, 73 Am Econ Rev at 695 (cited in note 3). Shirking may be a special problem here, too, though it can be mitigated by repeat-player dynamics. See Gallini and Scotchmer, *Intellectual Property* at 58 (cited at note 36).

43 See, for example, Landes and Posner, *The Economic Structure of Intellectual Property Law* at 9 (cited in note 2). Importantly, IPRs are also vulnerable to rent-seeking. See Kapczynski, 59 UCLA L Rev at 987 (cited in note 32).

44 See Amy Kapczynski and Talha Syed, *The Continuum of Excludability and the Limits of Patents*, 122 Yale L J 1900, 1920 (2013).

45 See id at 1928–37.

to be systematically more amenable to exclusion than others.[46] In such cases, market-based exclusion rights will yield inadequate incentives to innovate, and they may also distort innovation incentives toward more excludable solutions.[47] A nontraditional carrot that does not rely on excludability for its effect, however, can promote both highly excludable and highly nonexcludable innovation symmetrically and allow the innovator to choose the better (or cheaper) path to the desired good.

There is a broader way to articulate this point: nontraditional carrots, and in particular inducement prizes, can be designed to be agnostic about the mode of innovation chosen and, therefore, to promote both excludable and highly nonexcludable solutions to a problem. For example, a government might offer a prize for the best means of increasing exercise rates among children and award the prize to the party that provided the best evidence of increased exercise, whether through a new (excludable) dance-based video game or through a popular new (highly nonexcludable) playground game. Prizes can even be designed to be agnostic about whether improvements come through innovation or rather through rediscovery or adoption of existing innovations. For example, a government might give every school that achieved a certain exercise rate among third graders a financial reward regardless of whether it achieved such a rate through innovation, adoption, or rediscovery. Exclusion rights instead require some modicum of originality or novelty and so do not encourage actors to select the cheapest and most effective alternative among as wide a range of activities.[48]

Another benefit of nontraditional carrots also emerges from the recent literature. The conventional account, which promotes

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46 For example, "uses of information goods that manifest in relatively more immaterial fashion will be more difficult to exclude, because the state of technology makes monitoring intangible processes (like thoughts) more difficult than monitoring more tangible things." Id at 1920.

47 Because excludability is a continuum, and because it does not vary directly with social value, traditional carrots also threaten to distort allocative decisions. Imagine an innovator with two ideas to reduce the health costs of obesity, one of which is technological (for example, a pill or an exercise machine, and so highly excludable), and one of which is nontechnological (for example, a new exercise regime, which must be validated and so is expensive, but which is highly nonexcludable). Traditional carrots will promote the former over the latter, even if the latter would cost less or be more effective. For a description of this point in some detail, see id at 1921–23.

48 See, for example, 35 USC § 102(a) (outlining the novelty requirement in patent law); *Feist Publications, Inc v Rural Telephone Service Co*, 499 US 340, 363 (1991) ("As a constitutional matter, copyright protects only those constituent elements of a work that possess more than a *de minimis* quantum of creativity.").

IPRs because of their allocative advantages, assumes that markets produce accurate signals for the value of innovation.[49] However, markets in practice are systematically vulnerable to failure. In neoclassical terms, such failures may result, for example, from pervasive externalities (such as the pollution caused by motorists) or from information asymmetries (for example, those that exist between a sick person and a pharmaceutical company or between a driver and the car company that designs a car's safety systems).[50] Scholars of behavioral economics and psychology instead stress biases in perception or cognition, such as the "optimism bias," which can discourage consumers from investing adequately in innovations that reduce the likelihood or cost of accidents.[51] More-foundational critiques of markets also point out that market-based measures of social value will systematically underestimate the social value, in welfarist terms, of innovations that serve those with limited ability to pay.[52] When markets are a poor measure of value—because we value things that are not measured well in markets, or because of systematic problems with the signals transmitted in market transactions—then market-based signaling will yield inadequate (and distortive) incentives.

Traditional carrots have not only the advantages but also the disadvantages of market-based signaling. When markets fail, signals are distorted. Nontraditional carrots, by contrast, can directly reflect values or information that are not well presented in markets. When pollution externalities are endemic, for example, exclusion-based solutions such as patents for pollution-reducing technologies will simply replicate them. By using a nontraditional carrot, the rewards available to innovators can be brought closer to their projected social values.[53] Markets also

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49 See Glenn C. Loury, *Market Structure and Innovation*, 93 Q J Econ 395, 401–03 (1979) (developing models of R & D investment assuming perfect market valuation).

50 See David J. Bjornstad and Marilyn A. Brown, *A Market Failures Framework for Defining the Government's Role in Energy Efficiency* *25 (Joint Institute for Energy & Environment, June 2004), archived at http://perma.cc/7DGQ-JWSR.

51 Christine Jolls and Cass R. Sunstein, *Debiasing through Law*, 35 J Legal Stud 199, 207–08 (2006) (explaining that, because of optimism bias, consumers may not adequately assess the risks associated with the products they use).

52 For more on this point, see Kapczynski, 59 UCLA L Rev at 999–1000 (cited in note 32).

53 The same point can be made with respect to, for example, the divergence between market value and social value that is generated by the problem of inability to pay. See id at 993 n 86. A prize or penalty can directly generate incentives to serve poor

predictably misfire when they depart from competitive conditions, such as when there are significant barriers to market entry.[54] Imperfect competition exists in many domains, both market (as in cases of monopoly and monopsony) and nonmarket (as for many state-based entities, which may have a captive audience or effective monopoly). And when this is so, market signals will likely lead to insufficient innovation, and nontraditional measures may be superior to traditional carrots.

These newer arguments for the benefits of nontraditional carrots do not diminish the potential difficulties associated with such carrots. As noted above, the most important problem with nontraditional carrots is the significant informational burdens that they place on governments. For prizes in particular (which we focus on here as the most similar to innovation sticks), governments must establish the size of the carrot and thus must have a good sense of the value of the desired innovation. Also, there can be divergence between the things that governments can measure and the actual underlying phenomena that governments want to promote. For example, educators are familiar with the problem of "teaching to the test."[55] If we use test scores as a measure of student performance and award financial prizes to high-performing schools, schools will teach to the test; this can be a problem if the test is an imperfect metric for multidimensional learning. The problem has been stated more broadly as "Campbell's law," which reflects the fact that "[t]he more any quantitative social indicator is used for social decision-making, the more subject it will be to corruption pressures and the more apt it will be to distort and corrupt the social processes it is intended to monitor."[56] (Not only may schools neglect important things that are not in the test but they may also encourage cheating by students or lobby to shape the tests in ways that advantage savvier schools.) This is a serious issue both for those who design nontraditional carrots and, as we will discuss later,

populations, and it can be set at a level far above the level of incentives that markets alone would provide. See, for example, id at 997–98.

54 See Daniel F. Spulber, *Regulation and Markets* 40–42 (MIT 1989).

55 See generally W. James Popham, *Teaching to the Test?*, 58 Educ Leadership 16 (Mar 2001).

56 Donald T. Campbell, *Assessing the Impact of Planned Social Change* *49 (Dartmouth College Public Affairs Center Occasional Paper Series, Dec 1976), archived at http://perma.cc/B6DE-WDL8.

for those who design innovation sticks.[57] (IP, we must not forget, has parallel problems: market signals diverge from social value whenever there are externalities, wealth effects, or other market imperfections, and exclusion rights do not symmetrically incentivize different kinds of information production.)[58] There are possible design responses, however, ranging from monitoring to the development of criteria that more closely track social value.[59]

Importantly, a government can use nontraditional carrots (and sticks) without knowing exactly what it wants in return, because carrots and sticks can be defined generally or can define the desired objective in negative terms ("create something *other than this*") rather than in positive terms ("create *that*").[60] But because it must set the level of the reward or fine, the government inescapably must project something about the costs and benefits of the desired shift, even if just at the break-even level.

While this projection can be a significant problem, it is important to note that it can also be mitigated. For example, the size of a prize need not be determined ex ante but can be decided ex post, when there may be better information available about demand.[61] A particularly important way to address the information

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57 For example, later we will describe Medicare-established "diagnosis-related groups," which help spur innovation in the ways that hospitals treat patients. The system nudges hospitals by capping reimbursements to a level influenced by the average of treatments for people with similar diagnoses. As Campbell's law suggests, there is a risk that hospitals will achieve the average in ways that undermine health outcomes—for example, by turning away sicker patients. See text accompanying notes 167–68.

58 For more on these market imperfections, see, for example, Kapczynski, 59 UCLA L Rev at 988–90 (cited in note 32).

59 See, for example, James Love and Tim Hubbard, *The Big Idea: Prizes to Stimulate R&D for New Medicines*, 82 Chi Kent L Rev 1519, 1534–43 (2007) (proposing an R & D prize for pharmaceuticals based on measurements of the quality-adjusted life-years secured by any given technology).

60 For example, the government can use either a carrot or a stick to push companies away from the use of certain toxic chemicals or energy-hungry devices. Instead of specifying what should replace incandescent lightbulbs or CFCs, governments can give companies incentives (such as tax rebates for alternative units sold) or penalties (such as fines for offending units sold or emitted) and leave it to others to come up with alternatives. What is inescapable is the government's need to establish some rough accounting of costs and values in order to determine whether such programs will cost more than the amount that will be gained. When the government defines a goal in the negative, there is also the risk that alternatives to the negative will generate similar or worse effects. CFCs, which are discussed below, provide a real-world example of this problem. See notes 157–58 and accompanying text.

61 Professor Michael Kremer's patent-buyout provision, which uses an auction mechanism, is an example of this technique. See Michael Kremer, *Patent Buyouts: A Mechanism for Encouraging Innovation*, 113 Q J Econ 1137, 1146–47 (1998). So too is the model, put forth by Professors Steven Shavell and Tanguy van Ypersele, of a prize

problem that has not been emphasized in the IP literature involves yardstick incentives, which tie the size of rewards or punishments to the yardstick of one's peers. In 1985, Professor Andrei Shleifer's *A Theory of Yardstick Competition* provided an elegant stylized model showing why yardstick incentives could better "assure cost control, prevent waste, and promote cost-reducing innovation."[62] In his model, regulated utilities in different cities were allowed to charge customers a yardstick price equal to the average prices in the other cities. This yardstick price naturally incorporated both carrot and stick innovation incentives: utilities that innovated to reduce their costs below the average of their peers would earn a carrot of enhanced profits, while those utilities that fell behind would feel the sting of selling at a loss.[63] Shleifer's model showed that yardstick competition among the utilities—to garner the carrot and avoid the stick—was sufficient to induce optimal cost reduction as long as firms were reasonably identical or had heterogeneities that could be accounted for.[64]

For our purposes, it is also worth noting that yardsticks can be used to set the magnitude of an innovation carrot or stick—for example, by averaging the accomplishments of the relevant firms and establishing fines for laggards below a set threshold (that is, median, or within a certain percentile of the median), or establishing rewards for those who exceed the average accomplishments of their peers. A combination of carrots and sticks, as Shleifer envisioned, could also be accomplished with rewards and fines rather than via price setting. The central virtue of yardsticks in this context would be, as in Shleifer's model, their ability to help reveal the production costs of firms—here for innovation rather than energy production—more directly to governments.[65] Using yardsticks would minimize the upside risk of asking far too much of firms and thus generating widespread exit from an industry, since by definition some percentage of firms would either meet the standard or have demonstrated that the result is feasible. Especially if collusion is possible, however,

whose value is established indirectly, by market sales. See Steven Shavell and Tanguy van Ypersele, *Rewards versus Intellectual Property Rights*, 44 J L & Econ 525, 541–42 (2001).

62 Shleifer, 16 Rand J Econ at 319 (cited in note 21).

63 In our terms, this kind of yardstick competition would also allow the government to be agnostic about what technologies were best used to innovate and indeed whether innovation itself was feasible. More on this in a minute.

64 Shleifer, 16 Rand J Econ at 326 (cited in note 21).

65 See id at 320–21.

yardsticks could establish thresholds that are too low.[66] Allowing firms to trade liabilities or potential rewards has become common through the concept of cap and trade, and it may also improve the efficiency of nontraditional measures to promote innovation.[67]

Finally, even though the government does not usually know precisely how an industry will make nonobvious advances over prior art, some industries are affected by something like Gordon Moore's innovation "laws," and when they are so affected, they provide another metric that can reduce information costs for the government. Just as Moore observed that the number of transistors on integrated circuits tends to double every two years,[68] policymakers can take note of the fact that technological innovation predictably enhances the feasible fuel efficiency every year and can base future CAFE standards in part on those predicted advances. Figure 1 in Part III displays a similar innovation trend with regard to automobile fatalities.

In setting the trigger amount for a nontraditional carrot or for a stick, the government can either augur what is technologically possible (à la CAFE) or rely on the yardstick of what competitors have shown to be possible. Each approach has its own relative strengths. For example, as applied to sticks, the augural approach might, in equilibrium, avoid the imposition of many penalties, while the yardstick approach plausibly subjects half the industry to penalties, with the attendant distortion inefficiencies associated with those payments. Yardstick sticks by themselves also might not produce sufficient inframarginal incentives. Manufacturers who know that they are likely to fall below the CAFE fleet miles-per-gallon (mpg) cap may have insufficient incentives to pioneer new fuel-efficiency innovations. One response to the inframarginal incentive problem would be to layer different carrot or stick incentives for different margins of success. Thus, we are attracted to the way that the CAFE penalties are combined with patent rewards to create a carrot-*and*-stick regime in which some manufacturers are rewarded via patents for

66 See id at 327 (discussing the problem of collusion).

67 For a formal argument in this regard, see Pénin, *Should We Oblige Firms to Invest in R&D?* at *8–10 (cited in note 6) (describing the virtues of hypothetical tradable permits to "not invest in R&D").

68 See Gordon E. Moore, *Progress in Digital Integrated Electronics*, 21 IEDM Technical Digest 11, 13 (1975).

pioneering innovations and other manufacturers are punished via CAFE if they lag behind the possible.[69]

These strategies can help compensate for the inherent weaknesses of the measures that we term "nontraditional," but they do not establish any broad theory of superiority across all domains. We will return to the question of the circumstances in which nontraditional carrots and sticks are likely to be preferable to traditional carrots,[70] but first we must have in hand a better understanding of innovation sticks.

B. Introducing Innovation Sticks

The IP literature has been focused exclusively on carrot-based approaches to innovation.[71] This is puzzling in part because the growing carrots-versus-sticks literature suggests that sticks have potential benefits over carrots.[72] Foundational law and economics work suggests that incentives should be equivalent whether structured as a penalty or as a reward, so that "any behavioral change induced by promising compliers a $100 reward can also be obtained by threatening violators with a $100 punishment."[73] Recently, De Geest and Dari-Mattiacci have, however, called attention to certain systematic differences between carrots and sticks. Most importantly, in equilibrium, sticks do not need to be paid. Carrots, by contrast, can be used

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69 Note, however, that because patent incentives are keyed to markets (and because of the externalities of pollution), patents here will provide less incentive to engage in pioneering innovation than is socially desirable. See Wright, 73 Am Econ Rev at 691–93 (cited in note 3). Still, the availability of patents may induce some innovation because consumers value fuel economy (even if less than is socially optimal), and when combined with sticks, patents can provide insurance against sticks that are too small. Layering carrots and sticks can also provide protection against the problem of undercompensation.

70 See Part I.C.

71 See, for example, Gallini and Scotchmer, *Intellectual Property* at 52 (cited in note 36); Wright, 73 Am Econ Rev at 691 (cited in note 3).

72 See generally, for example, Ian Ayres, *Carrots and Sticks* (cited in note 25) (explaining the power of "commitment contracts," a type of stick in which one commits to receiving punishment upon failure to achieve the contracted goal). See also De Geest and Dari-Mattiacci, *Carrots versus Sticks* at *2 (cited in note 7) (drawing "a broad picture of the differences between carrots and sticks" and noting that sticks have many advantages over carrots); Gerrit De Geest and Giuseppe Dari-Mattiacci, *The Rise of Carrots and the Decline of Sticks*, 80 U Chi L Rev 341, 349 n 27 (2013).

73 De Geest and Dari-Mattiacci, 80 U Chi L Rev at 347 (cited in note 72). As Professors De Geest and Dari-Mattiacci point out, this is implicit in R.H. Coase, *The Problem of Social Cost*, 3 J L & Econ 1, 7 (1960). See De Geest and Dari-Mattiacci, 80 U Chi L Rev at 354 n 44 (cited in note 72). See also Pénin, *Should We Oblige Firms to Invest in R&D?* at *3–4 (cited in note 6) (making a similar reference to Professor Ronald Coase's work).

up—if they are paid as a reward to one person, they cannot also be paid to another.[74]

De Geest and Dari-Mattiacci also gesture to possible differences between carrots and sticks in behavioral terms. If actors are subject to loss aversion, for example, then sticks may be more powerful motivators than carrots, even if the fines and benefits are otherwise equivalent.[75]

These same arguments also suggest a potential role for innovation sticks. The concept of innovation sticks, however, is sufficiently unfamiliar that it is worth describing their usage and effects. Like innovation carrots, innovation sticks come in many possible forms and share only a basic definitional quality: they apply penalties to those who do not innovate rather than offer rewards to those who do. As with carrots, innovation sticks may be applied to inputs or outputs and may use various metrics of success, from the technologically specific to the technologically agnostic.

Table 1 gives examples in each of these areas and begins to develop a rudimentary typology of innovation sticks. (Table 1 also includes analogous carrots in each case to help reveal the symmetries and differences between carrots and sticks in this domain.)

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[74] See De Geest and Dari-Mattiacci, *Carrots versus Sticks* at *14–16 (cited in note 7). This conclusion relies on a stylized set of assumptions—for example, that sticks do not have any economic or distributional effects. See id at *10. In addition, as the literature on racing makes clear, sometimes carrots clearly induce efforts without having to be paid. Indeed, this is a canonical definition of a race: only the winner receives the reward, but many others exert themselves to try to reach the goal. See Kapczynski, 59 UCLA L Rev at 984 (cited in note 32).

[75] See De Geest and Dari-Mattiacci, *Carrots versus Sticks* at *26 (cited in note 7) ("[W]hen agents have loss aversion . . . negative incentives may be more effective than positive incentives."). One of us is a cofounder of a website, www.stickK.com, that leverages loss aversion by letting users put money at risk if they fail to reach their goals. See Michael Abramowicz and Ian Ayres, *Commitment Bonds*, 100 Georgetown L J 605, 616 (2012). Sticks, like carrots, may also crowd out intrinsic motivation and thereby dampen innovative efforts. See Bruno S. Frey and Reto Jegen, *Motivation Crowding Theory*, 15 J Econ Surveys 589, 589 (2001) (surveying the empirical support for the idea that "external intervention via monetary incentives or punishments may undermine, and under different identifiable conditions strengthen, intrinsic motivation"). Presumably, wealth effects may also be important in understanding the differential impact of carrots and sticks. In considering various behavioral-economic impacts, it may also be important to distinguish between individual and corporate inventors.

TABLE 1. TYPOLOGY OF INNOVATION STICKS

		Metric for Success	
		Technology Specific	Technology Agnostic
Punishment [Reward] Contingent on	Inputs	Researcher who fails to spend X hours on researching electric cars is fined [Grants for electric car researchers]	Researcher who fails to spend X hours on research is fined [Grants that are agnostic about research domain—for example, grants for National Institutes of Health programs]
		Company that fails to spend X amount on research to improve batteries is fined [Grants or R & D tax credits for companies that engage in battery research]	Company that fails to spend X amount on general R & D is fined; effectively a regressive tax on R & D expenditures [Grants or R & D tax credits for R & D broadly defined]
	Outputs	Researcher who fails to create new battery type is fined [Patents or prizes for new batteries]	Researcher who fails to produce innovations that diminish emissions is fined [Patents or prizes for emissions-reducing technologies or strategies]
		Car company that fails to market electric cars is fined [Patents or prizes for electric cars]	Car company that fails to decrease pollution emissions in its fleet by X amount is fined [Patents or prizes for emissions-reducing technologies or strategies]

These different forms of incentives impose distinctive informational demands on the government. Some of the informational demands that sticks make are also present for nontraditional carrots. For example, for sticks as well as for prizes and grants, government actors need good information on the value of the innovation they are seeking.[76] Technology-specific incentives likely require better information than more-general incentives to innovate, as picking a very specific winner (electric cars) may be harder than picking a general aim (reducing pollution). For those carrots and sticks that are keyed to inputs rather than outputs, there is a risk of shirking or waste.[77]

More interesting are the areas in which the information requirements of innovation sticks diverge from those of equivalent nontraditional carrots.[78] Innovation sticks would seem for one reason in particular to require more information than do nontraditional carrots: with sticks, the government needs good information about the potential set of innovators—but because people will not self-nominate for sticks, governments must identify potential innovators without their help.[79] When the government awards carrots, individuals will come forward, as occurs when potential innovators apply for government grants. There is a concomitant risk that people will falsely nominate themselves—for example, by overstating their potential merit as researchers or by gaming the definition of a prize. But the costs of detecting lying and cheating, particularly in a repeat-player

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[76] Importantly, though it is not often stressed, the government also faces information problems when defining the contours of exclusive-rights regimes, such as in determining patent duration or the set of exclusive rights available in copyright. See Amy Kapczynski, *Intellectual Property's Leviathan*, 77 L & Contemp Probs 131, 140–42 (2014).

[77] Although we do not pursue the issue here, it seems likely that there are differences between carrots and sticks from a behavioral perspective. For example, loss aversion might make individuals who are facing sticks less likely to shirk. However, some of the sticks we identify are so far from the current baseline and so violative of basic liberal commitments (for example, of the freedom of research) that their effects on individuals might well be counterproductive.

[78] We focus here on nontraditional carrots, because traditional carrots make use of markets to provide key informational signals. See Kapczynski, 59 UCLA L Rev at 982–83 (cited in note 32). Sticks that would do the same are very difficult to imagine. (Perhaps the government might create a tax on low sales, for example, assuming that companies with low sales are less innovative. But the sales—markets, that is—would set the level of the fine.) The trade-offs between sticks and nontraditional carrots on the one hand and market-based exclusion rights with respect to information on the other are discussed in some detail above. See Part I.A.

[79] Even if the government established a default fine, thus prompting individuals to come forward to claim an exemption, the government would still have to define at the outset the appropriate targets for the fine. With a prize, the government might leave that set open, suggesting that anyone who could build a better mousetrap could come forward to claim the reward. It seems far less plausible to fine everyone who fails to build a better mousetrap and revoke the fine for the set of individuals who come forward. It would also almost certainly penalize people with no capacity to innovate in the relevant way, raising a distributional concern that we discuss later. See text accompanying notes 84–86.

environment, are plausibly smaller, at least much of the time, than the efforts needed to define the potential set of innovators.

Finally, carrots seem to have informational advantages when upper limits to performance are hard to define.[80] Sticks create thresholds below which parties must not fall and are consequently preferable when the lower limit is known and clear. For example, sticks are good for enforcing rules about when to get to work (when it is clear that it is best if all employees get to work by 9:00 a.m. and there is no value in getting there earlier), but carrots may work better when individuals' sales quotas are concerned if management does not know in advance what the possible sales amounts are.[81] Nonobvious innovation is a domain in which it may often be difficult to determine upper limits. But many other modes of innovation—including the diffusion of know-how that is required to figure out how to get an idea to work in a different setting—may present domains in which the lower limit is more knowable.

Put more generally, as De Geest and Dari-Mattiacci have noted in recent work, sticks may be best in "simple" settings, in which "citizens have more or less equal compliance costs and the lawmaker knows these costs and asks for equal efforts from all citizens."[82] In such cases, "sticks are superior because the lawmaker can easily set them high enough so that all citizens comply," thereby reducing costs as well as the distortions associated with the need to raise money to pay out for carrots.[83] But in more-complex circumstances, lawmakers may know little about what to expect from each citizen[84] and may also presumably have difficulty knowing exactly how to define what they want. It may be relatively easy to determine who should be forbidden to commit assault and easy to set the size of the penalty and define the forbidden act. But it may be much more difficult to decide who should build a better lightbulb, and it may also be difficult to know the costs and precise criteria of determining the success

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80 See, for example, Edward P. Lazear, *Labor Economics and the Psychology of Organizations*, 5 J Econ Persp 89, 104 (1991) (discussing situations in which performance output or input has no value above or below some critical value); De Geest and Dari-Mattiacci, 80 U Chi L Rev at 349 n 26 (cited in note 72) (noting that the ease of setting limits to performance influences the choice between carrots and sticks).

81 See De Geest and Dari-Mattiacci, 80 U Chi L Rev at 349 n 26 (cited in note 72).

82 Id at 345.

83 Id.

84 See id (noting, in particular, that governments "may not know which citizen should spend time composing songs").

of that lightbulb.[85] In addition, when the government requires particular efforts from certain citizens, it runs a risk of singling out precisely those individuals whose cooperation is most needed, causing distributional distortions and "artificially impoverishing those from whom much is required."[86] This is one reason why some of the sticks described above—for example, imposing fines on researchers who fail to invent a new form of battery—seem particularly ill-advised. Importantly, though, the government will sometimes have good information about the set of potential innovators as well as the value of their innovations. The CAFE standards, described below, are a good example because the government understands a great deal about the risks of climate change and the contributions made by the transportation sector.[87]

Innovation sticks also have a second major drawback in the innovation domain: they do not compensate innovators for their investments.[88] One reason that the IP literature focuses so strongly on carrots may be that it assumes that, in equilibrium, compensation is required to obtain sufficient levels of investment in innovation. That in turn is because innovation is assumed to be expensive and to result in discrete goods that can be readily copied by competitors and that have a universal (or at least widespread) utility.[89] These assumptions drive the conclusion that some form of compensation—whether via exclusion rights or government funding—is needed to produce innovation in adequate amounts under competitive conditions.

One response to this problem will be discussed in a moment:[90] innovation sticks can be applied along with traditional or nontraditional carrots, and when these tools are combined, this

85 To refer back to our earlier conversation, these difficulties should be compared to the difficulties of the alternative modes of influencing the allocation of inventive efforts. See Part I.A. For example, if carbon emissions are too cheap, then markets (and consequently, patents) also have a serious allocative problem. In other words, the information problem in question is a comparative one, and it cannot obviously be resolved in favor of markets once we have a more realistic picture of markets in view.

86 De Geest and Dari-Mattiacci, 80 U Chi L Rev at 345 (cited in note 72).

87 See Part II.A. Notably, the companies affected by the CAFE standards are also free to contract with others to find the cheapest means of meeting their regulatory burdens. When such contracting is possible, the quality of government information about who will be the best innovator is less important.

88 See De Geest and Dari-Mattiacci, 80 U Chi L Rev at 363 (cited in note 72).

89 See, for example, Landes and Posner, *The Economic Structure of Intellectual Property Law* at 17 (cited in note 2); Wright, 73 Am Econ Rev at 691 (cited in note 3).

90 See Part I.C.

will help address problems of undercompensation. Importantly, though, innovation sticks may also be useful in other domains in which carrots are either unavailable or ineffective. We have in mind two domains in which sticks may be used without associated carrots: domains in which free rider effects are absent (though not, we assume, because of exclusion rights) and domains in which market disciplines do not apply to actors (and so when exit will not be the result of the application of penalties). We address these two issues in turn.

First, free rider effects do not always accompany innovation. Information is not always expensive, not always readily copied, and not always useful to a broad range of competitors. It is increasingly clear that innovation has many modes, only some of which correlate well to the assumptions of the public-goods account of information.[91] For example, there is a growing literature on "social innovation,"[92] a term used, inter alia, to refer to innovations that restructure relations within organizations or organizations themselves, to process-oriented innovations aimed at solving social problems (such as traffic regulations or medical screenings), to political innovations (such as ideas for legislation or social programs), and to innovations in "lifestyle" (such as how to express one's values or aspirations or how to allocate one's resources).[93] Even technological innovation need not have the qualities of public goods,[94] but these other modes of innovation are still more likely to evade one or more of the requirements of the public-goods account. For example, these modes of innovation

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[91] This is a corollary to the point about nonexcludability raised above. See Part I.A. There, we note that different modes of innovation may be differently excludable even in the presence of exclusion rights, with the implication that public-goods problems can exist that exceed exclusion rights' power to remedy. Here, we point out that different modes of innovation may also generate greater or fewer public-goods problems. When there are few public-goods problems, undercompensation is much less of a risk and overcompensation may well be a greater concern.

[92] The term "social innovation" is used in many different disciplines and is subject to many definitions. See generally Dominik Rüede and Kathrin Lurtz, *Mapping the Various Meanings of Social Innovation: Towards a Differentiated Understanding of an Emerging Concept* (EBS Business School, July 2012), archived at http://perma.cc/2ZX7-PAQR.

[93] See generally Wolfgang Zapf, *The Role of Innovations in Modernization Theory*, 1 Intl Rev Sociology 83 (1991). The term "social innovation" is also used in many other ways, for example, in referring to new modes of "need satisfaction," a category that includes technological innovations such as the personal automobile. Id at 88. See also Rüede and Lurtz, *Mapping the Various Meanings of Social Innovation* at *4–5 (cited in note 92).

[94] For example, technological innovation is not necessarily nonexcludable without law if secrecy is effective. It also does not face substantial free rider problems if it is useful to only one party or needs modification before it can be useful to others.

may be relatively inexpensive and thus endemic to certain social circumstances. This holds even under conditions of free copying. (For example, this category would include minor legislative reforms or simple changes to organizational workflow.) Some such innovations may result in goods that have utility for only a small number of people (as when a human resources department figures out how to resolve a dispute between two employees) or that are difficult to copy and therefore not subject in any meaningful way to the problem of nonexcludability. Finally, some forms of innovation might be best understood as processes themselves—which is to say, as practices of continual revision that produce not discrete, stable products that may be copied but rather an ongoing string of minor innovations that have been revised by the time they might be visible to others.[95]

In this Article, we adopt a broad conception of what it means to innovate. Innovation includes not only the invention of a new technique or mechanism that is expensive and subject to free riding in the absence of exclusion rights but also the invention of new techniques and mechanisms that are inexpensive or that do not face free rider problems—either because they are useful only to a few or because they are rapidly updated in a fashion that leaves natural lead time in place. For us, innovation policy should also appropriately incentivize the diffusion of information insofar as it may require one kind of innovation for someone to learn what another already knows and another kind of innovation for someone to learn how to translate that learning to practice in a particularized setting. Because undercompensation may be less of a risk than overcompensation in these alternative forms of innovation, sticks may play an important role.

A possible objection arises: If these other modes of innovation lack the indicia associated with the IP and innovation-economics literature, are they consequently uninteresting from a policy perspective because they are likely to be produced in adequate amounts without any particular social intervention? In some cases, perhaps so.[96] When the conventional public-goods

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95 We can think of this domain as one in which a first-mover advantage sufficient to incentivize innovation still exists. See, for example, J.H. Reichman, *Of Green Tulips and Legal Kudzu: Repackaging Rights in Subpatentable Innovation*, 53 Vand L Rev 1743, 1770 (2000) (explaining that when innovation costs are low, a first-mover advantage is available).

96 We set aside here the possible interactions between innovation policy and disclosure. While information that can be kept secret may be adequately incentivized, there

qualities of information are lacking, competitive markets might be expected to perform well. If our local grocery store, for example, internalizes much of the value of improvements in its organizational workflow, *and* if such innovation is cheap, impossible to copy, or not valuable to competitors, then we can assume that such innovation will occur in adequate amounts without the need for additional policy interventions.

But innovation markets sometimes fail. Innovation sticks can help calibrate incentives when this is so, and they may be especially useful precisely when potential innovators face only modest free riding risks but existing market conditions generate too little demand for innovation from a social perspective. Similarly, when there are significant barriers to market entry—as in the case of a monopsony or monopoly, or when the relevant players are state actors that are insulated from competition—we need not worry as much that undercompensation will lead to exit from an industry.

C. The Costs and Benefits of Sticks

To synthesize the foregoing discussion, the case for innovation sticks shares much in common with the case for nontraditional carrots: both sticks and nontraditional carrots may be especially useful in situations in which we worry about the deadweight losses associated with exclusive rights in information and in which market signals diverge in predictable ways from what we desire as a social matter. They are also particularly useful to provide incentives to actors that do not operate in a competitive-market setting or that are precluded from profiting from exclusion rights. In addition, both sticks and nontraditional carrots can be designed to be agnostic as to the form of innovation used, as well as to whether improvements come through new innovations, greater adoption and dissemination of existing innovations, or rediscovery of old innovations.

Sticks and nontraditional carrots also have downsides: in particular, they are information intensive. Regulated actors may also game the criteria of success or try to influence these criteria to their advantage. There are risks here, including the risk of amplifying the advantages of large players and incumbents, who might have better resources than new entrants and so be better

may be social welfare problems with allowing or encouraging secrecy insofar as that information is valuable to others (or "nonrivalrous," in conventional terms).

able to mobilize to meet—and also to change—the governmental criteria. We do not mean to downplay these problems. But we do mean to suggest that they are not a fortiori more troubling than the disadvantages associated with IPRs (which include a tendency to favor incumbents).[97]

A further question arises: When might we prefer sticks to nontraditional carrots? The central insight that we draw from the above analysis is that if compensation is not required to induce innovation, and if efficiency is our metric, sticks will be preferable to nontraditional carrots. "Carrots may distort by overpaying; sticks by underpaying"[98]—but when compensation is not required, the only risk is of distortion by overpaying. Though the existing theoretical account on which the IP and innovation literature is based tends to assume that undercompensation is the chief risk, there is more and more recognition that, outside of a few special fields (such as pharmaceuticals), conventional competitive markets may in fact generate sufficient information without additional rewards.[99] In such cases, carrots will overcompensate and yield distortions. These distortions stem from both the taxes required to fund the reward and the excessive effort or racing that may attend the overcompensation. If markets are otherwise functioning well, no intervention at all may be needed in these cases. But when there are pervasive externalities or when the targets are nonmarket actors, sticks are likely to be a better innovation tool than nontraditional carrots.

Put another way, sticks are especially appropriate when we expect that the needed innovations do not have the conventional

[97] IP may advantage incumbents, too, who similarly can organize to influence the nature of IP law and so perpetuate their advantage. Professor Yochai Benkler has argued that IP has centralizing effects, because those who buy up larger stocks of knowledge can avoid the transaction costs of purchasing licenses on the open market. Incumbents can impose asymmetric costs on more-open innovators because they can exclude open innovators but are not themselves excluded from more-open innovation. See, for example, Yochai Benkler, *Intellectual Property and the Organization of Information Production*, 22 Intl Rev L & Econ 81, 88–89 (2002) (noting that integration among multiple incumbent firms "avoids transaction costs associated with purchase of information inputs owned by others").

[98] De Geest and Dari-Mattiacci, 80 U Chi L Rev at 368 (cited in note 72) (emphasis omitted).

[99] See Richard Posner, *Do Patent and Copyright Law Restrict Competition and Creativity Excessively?* (The Becker-Posner Blog, Sept 30, 2012), archived at http://perma.cc/9VWY-X2XK (suggesting that the ostensible need for patents in inventive industries has been overestimated). See also Michele Boldrin and David K. Levine, *Against Intellectual Monopoly* 4 (Cambridge 2008) (arguing that patent protection is primarily used to prevent economic progress and hurt competitors).

qualities of public goods (for example, if they stem from forms of social innovation that may be low cost or valuable to only a single entity) but we are nonetheless concerned that market-based signals will not suffice to induce the innovation we want. Among other reasons, this may be because of pervasive externalities that are practically or politically difficult to address with a general tax, or because the target entities are sheltered from market pressures. Nontraditional carrots, in turn, have a comparative advantage when public-goods issues (or free rider problems) are present but exclusion rights are inappropriate—for example, when exclusion rights are ineffective, are distortive, or generate unacceptable deadweight loss.

Other factors, too, are relevant to the choice between sticks and nontraditional carrots. Both are information intensive and may, for this reason alone, be inappropriate in many cases. To implement innovation sticks, the government must identify potential innovators and establish a value for the innovation desired.[100] If the government knows little about the value of different dishwasher designs, for example, it cannot design a good system to induce the innovation of dishwashers. But if it does have good information—for example, if it "knows" better than markets the true long-term cost of the energy consumption of a dishwasher—then nontraditional measures may indeed be appropriate regarding this dimension. Whether the information costs of sticks will be higher than those of nontraditional carrots will be case specific, and it will depend significantly on whether the government is reasonably able to determine the plausible set of innovators (or the ease of contracting thereafter). Also important is whether the aim is to establish a uniform lower bound (favoring sticks) or to direct efforts toward an unknown upward bound (favoring nontraditional carrots).[101]

There may also be differences between carrots and sticks regarding the government's ability to credibly deploy one or the other. As we will see in Part II, the government has, in several of our examples, stopped short of applying penalties when it

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[100] In some settings, the government's task is to identify the innovators or the entities who are well placed to serve as Coasean contractors. The threat of CAFE penalties, for example, gave laggard car manufacturers good incentives to license innovations to improve their fleets' fuel efficiency. See Part II.A.

[101] Foreshadowing our examples to come, it is perhaps not surprising that sticks have been widely used in the environmental context because of the feasibility of establishing a uniform threshold—such as for energy use or for the use of harmful chemicals—that we wish to apply broadly to all actors. See Part II.A.1.

became clear that the desired innovations—for example, in zero-emissions automobiles—were not forthcoming. This suggests that it may be difficult for the government to credibly commit to the deployment of sticks, perhaps more so in the domain of innovation than elsewhere. De Geest and Dari-Mattiacci, notably, make the opposite point regarding sticks generally: because sticks generate revenue for the government rather than require expenditures, De Geest and Dari-Mattiacci suggest that a downside of sticks is that they may be too easy for governments to deploy and thus may have more potential for abuse.[102] This may, however, be context specific and dependent on both the social meaning of the activity in question and the actors who are targeted. For example, it may be easy for the government to overuse sticks as applied to convicted felons, who are easily stigmatized and politically weak (and often disenfranchised[103]). But it may be much more difficult for the government to apply sticks to powerful industries that are being asked to do something perceived as affirmative—namely, to innovate—in a context in which firms may be able to credibly complain that the task was impossible and to exert political influence to resist the sticks.[104] Nontraditional carrots face less resistance from their targets but more resistance from those who foot the bill. But nontraditional carrots such as prizes may also face a credibility problem, because governments may have incentives to renege after innovators have sunk their costs.[105] The point about political economy might be generalized this way: Sticks may in general be more credible against small and politically weak actors, but by the same token, they are more prone to abuse against these same actors. Carrots may be more credible when applied to large and politically powerful actors, but by the same token, the government may be more likely to overuse carrots against these actors and underuse sticks. Whether sticks or nontraditional carrots

[102] See De Geest and Dari-Mattiacci, *Carrots versus Sticks* at *16 (cited in note 7).

[103] See Elizabeth Hull, *The Disenfranchisement of Ex-felons* 29–30 (Temple 2006).

[104] See, for example, Steven L. Puller, *The Strategic Use of Innovation to Influence Regulatory Standards*, 52 J Envir Econ & Mgmt 690, 690 (2006) (noting that firms may behave strategically by failing to innovate to meet regulatory standards when they are not "regulation-takers").

[105] See Scotchmer, *Innovation and Incentives* at 32 n 2 (cited in note 3) (citing several historical examples in which governments may have reneged on prize promises). Contract law or reputational concerns might help mitigate this problem for carrots. We thank Professor Alan Schwartz for pressing us on this point.

face greater credibility problems may thus be context specific and is another relevant consideration for policymakers.

Sticks and nontraditional carrots may also have different implications from a behavioral or distributive perspective. In part because of the aforementioned malleability of baselines,[106] context is likely important. But context may be of nontrivial importance to policy if, for example, a stick requires that those actors from whom we seek great effort also bear a significant risk of penalty—particularly if penalties are understood in a social, rather than a Coasean, fashion as punishments that generate particular aversion and approbation. In addition, distribution can also affect efficiency, as it does when wealth effects are present.[107]

Finally, policymakers can deploy carrots and sticks (whether traditional or nontraditional) together and may often wish to do so. Some forms of yardsticks employ both carrots and sticks, as described above.[108] And whenever sticks are applied, if patent law applies in relevant ways to the field in question, those sticks will work in conjunction with traditional carrots. In fact, in many cases, sticks may be most useful in conjunction with carrots, so that carrots can help incentivize pioneers and sticks can help encourage laggards or correct market failures that are not addressed in other ways. There are additional complexities raised by the use of these tools together, however. The design of each should be appropriate to the concerns identified above (so that, for example, the carrots are well calibrated to the domain in which undercompensation is a concern). We also leave for another day certain questions that arise when these tools are used together, such as the potential anticompetitive effects that may arise when traditional carrots are combined with sticks.[109]

Ultimately, once all these different tools are brought into view, we face the ordinary—and difficult—questions about efficiency

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106 See note 13 and accompanying text.

107 As we discuss below, if one result of innovation sticks in the educational context were that schools with few resources ended up with still-fewer resources against a backdrop in which resources are not justly distributed, this would be undesirable on distributive grounds and on efficiency grounds. See Part II.B.2.

108 See text accompanying notes 62–64.

109 For example, requiring every manufacturer to use a new, environmentally friendly technology might bestow excessive market power on the technology owner. In such settings, compulsory licenses may be appropriate. See, for example, 42 USC § 7608 (allowing the attorney general to require the owner of any patent that is not "reasonably available" to license the patent if such licensing is necessary to comply with certain aspects of the Clean Air Act and if "there are no reasonable alternative methods" to achieve compliance).

trade-offs. We do not claim here that innovation sticks are better than the alternatives. Rather, we attempt to establish a set of important (but preliminary and noncomprehensive) considerations that should inform their use and that can help policymakers decide among traditional carrots, nontraditional carrots, and sticks—or that might lead us to combine some of the above.[110]

II. EXISTING EXAMPLES

The theoretical case for innovation sticks made above is sufficient to suggest, under limited circumstances, the efficacy of threatening penalties for a failure to innovate. In this Part, we show that innovation sticks have already been implemented as a tool of federal policy to induce producers and states to innovate in order to improve performance in a variety of contexts. We develop several examples from the environmental context because of the importance and prevalence of sticks in this domain, and we then develop examples from other settings to illustrate the very diverse contexts in which sticks have been deployed or contemplated.

A. CAFE and Other Producer Penalties

1. Environmental sticks.

More than 30 percent of US greenhouse gas emissions are attributable to the transportation sector.[111] Increases in fuel efficiency are thus important to efforts against climate change and may also help mitigate the security and foreign affairs problems associated with the US reliance on fossil fuels. Consumers are not expected to internalize the benefits of the long-term environmental and political gains associated with improved fuel efficiency, making this area one that has long been the subject of regulation.[112]

[110] It is also worth noting that innovation sticks generate feedback information and can be adjusted accordingly. Ideally, sticks are not applied or are applied rarely. Sticks will be applied frequently when they are poorly designed and fail to induce effort or expect too much effort, suggesting a possible need for revision. See De Geest and Dari-Mattiacci, 80 U Chi L Rev at 371–72 (cited in note 72). As this suggests, one important point of comparison between different innovation mechanisms should be their relative openness to feedback, as well as their general adaptability and adjustability.

[111] Christopher R. Knittel, *Automobiles on Steroids: Product Attribute Trade-Offs and Technological Progress in the Automobile Sector*, 101 Am Econ Rev 3368, 3368 (2011).

[112] See Jacobsen, 5 Am Econ J: Econ Pol at 178 (cited in note 18) (noting that "[c]onsumer myopia . . . favors CAFE in order to correct consumer mistakes").

In 1975, Congress enacted the first CAFE standards in the aftermath of fuel shortages brought about by the Arab oil embargo of 1973–1974.[113] These standards set a fuel-economy standard in mpg that each car manufacturer has to meet for its fleet of new passenger cars in a given model year.[114] The standards were quite stringent in their early years, but they effectively stagnated in the 1980s, in part due to increases in the relative sales of light trucks and SUVs (which have generally been subject to more-lenient CAFE standards).[115] Very recently, new regulations were promulgated to substantially toughen fuel-economy requirements under CAFE: by 2025, manufacturers will be required to almost double the average fuel economy of new passenger cars and light trucks, which is projected to cut in half greenhouse gas emissions as compared to the 2010 fleet.[116]

The CAFE standards are a prime example of a regulatory innovation stick. If a car manufacturer fails to comply with the fuel-economy requirement in a given model year, it must pay civil penalties.[117] Under current regulations, the penalty totals $55.00 for each mpg that falls short of the set mileage standard, multiplied by the manufacturer's total production for the domestic market.[118] Such penalties are not trivial in real terms, and many manufacturers appear to have treated them as a "binding constraint."[119]

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[113] See Energy Policy and Conservation Act (EPCA), Pub L No 94-163, 89 Stat 871 (1975), codified as amended in various sections of Titles 15 and 42; David L. Greene, *CAFE or Price? An Analysis of the Effects of Federal Fuel Economy Regulations and Gasoline Price on New Car MPG, 1978-89*, 11 Energy J 37, 37–38 (1990) (recounting how the EPCA was a direct response to the fuel-price shock caused by the oil embargo). For an overview of the development of the CAFE standards since 1975, see Laura Hall, Note, *The Evolution of CAFE Standards: Fuel Economy Regulation Enters Its Second Act*, 39 Transp L J 1, 7–16 (2011).

[114] See EPCA § 301, 89 Stat at 902–03.

[115] See Knittel, 101 Am Econ Rev at 3368 (cited in note 111). For a discussion of the difference between cars and light trucks or SUVs, see NRC, *CAFE Report* at 1 (cited in note 10) (noting that in 2002 the CAFE standards were "27.5 mpg for passenger cars and 20.7 mpg for light trucks").

[116] 77 Fed Reg at 62627 (cited at note 12). See also Bill Vlasic, *U.S. Sets Higher Fuel Efficiency Standards* (NY Times, Aug 28, 2012), archived at http://perma.cc/55M9-MRJQ.

[117] See 49 USC §§ 32911–12. CAFE also permits some banking and trading of credits for companies that exceed the standards, so the central stick of the regulation is supplemented with a kind of a carrot. See 77 Fed Reg at 62649 (cited in note 12).

[118] 49 CFR § 578.6(h)(2).

[119] Donald Warren MacKenzie, *Fuel Economy Regulations and Efficiency Technology Improvements in U.S. Cars since 1975* *125 (unpublished PhD dissertation, MIT, June 2013), archived at http://perma.cc/D7CC-CJVS. See also Jacobsen, 5 Am Econ J: Econ Pol at 156 (cited in note 18). A few companies—such as BMW and Mercedes-Benz, which

In setting the current CAFE standards, the National Highway Traffic Safety Administration (NHTSA)—the agency responsible for implementing the standards via rulemaking—is required by law to mandate "the maximum feasible average fuel economy level that it decides the manufacturers can achieve in that model year" after considering four statutory factors: "[t]echnological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the nation to conserve energy."[120]

The CAFE program has long been understood to be technology forcing.[121] The agency interprets its statutory mandate as a requirement to set standards that "make it necessary for manufacturers to engage in research and development in order to bring a new technology to market."[122] However, the agency has also historically been cautious in projecting the pace of change, often keying its demands to technologies that have been proved or are close to fruition.[123] The agency does not limit itself to technologies that are already in existence, but in a short rulemaking time frame it will look just a few years into the future.[124] The recent increases in CAFE standards were accompanied by a much longer regulatory time frame (projecting out to the year 2025), so the agency considered not only "near term" technologies but also technologies "that are beyond the initial research

produce relatively small volumes of luxury vehicles—have chosen instead to violate the standard each year since model year 1987 and, in turn, have paid around $500 million in fines. See id at 155–56; *Vehicle Fuel Economy: Reforming Fuel Economy Standards Could Help Reduce Oil Consumption by Cars and Light Trucks, and Other Options Could Complement These Standards* *24 (GAO, Aug 2007), archived at http://perma.cc/3Z2Q-7F82.

120 77 Fed Reg at 62627 (cited in note 12). The agency has discretion to balance these factors. *Center for Biological Diversity v National Highway Traffic Safety Administration*, 538 F3d 1172, 1195 (9th Cir 2008) ("The EPCA clearly requires the agency to consider these four factors, but it gives NHTSA discretion to decide how to balance the statutory factors—as long as NHTSA's balancing does not undermine the fundamental purpose of the EPCA: energy conservation.").

121 See, for example, *Center for Auto Safety v National Highway Traffic Safety Administration*, 793 F2d 1322, 1339 (DC Cir 1986), quoting S Rep No 94-179, 94th Cong, 1st Sess 9 (1975) ("Congress created mandatory vehicle fuel economy standards, intended to be technology forcing, with the recognition that 'market forces . . . may not be strong enough to bring about the necessary fuel conservation which a national energy policy demands.'").

122 77 Fed Reg at 63015 (cited in note 12).

123 See id at 62668 (noting that the agency considers "technological feasibility" to exist when "a particular method of improving fuel economy can be available for commercial application in the model year for which a standard is being established").

124 See id.

phase, and are under development and expected to be in production in the next 5–10 years."[125] As a result, the agency engaged in what it called "augural" projections, meaning that the projections "represent NHTSA's current best estimate, based on the information available to the agency today, of what levels of stringency might be maximum feasible in those model years."[126] CAFE is thus a particularly interesting example for our purposes, both because it is deliberately modeled and understood as a stick-based regime to promote innovation and because in its latest iteration it has explicitly relied on agency efforts to project and demand technology beyond that which currently exists.[127]

There is also a significant body of literature evaluating the effects of the CAFE program. It is difficult to decisively distinguish the impact of the regulations from those of other background conditions, in particular from the impact of changes in gasoline prices. But many analyses have concluded that the program has had positive effects, particularly—though not only—because it has pushed companies to innovate in the area of fuel economy.[128] A comprehensive evaluation of the program was completed in 2002, after Congress charged a special committee within the National Academy of Sciences to investigate the efficacy of the CAFE standards.[129] That committee noted that fuel

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125 Id at 62642–43. The agency also noted that it did *not* set standards based entirely on conjecture. Id at 63015 ("[I]t would not be reasonable for the agency to predicate stringency on completely unforeseen future improvements in unknown technologies."). Some believed that the agency should do more, urging it to set standards based on more actuarial estimations. See id (describing the views of the Center for Biological Diversity). The agency demurred, citing its additional statutory obligation to consider economic practicability. Id.

126 77 Fed Reg at 62627 (cited in note 12). Because the statute requires the agency not to set standards more than five model years at a time, these standards must be revisited before they come into effect.

127 Note, however, that future standards will require new action before they are implemented. See note 126.

128 The program has also had costs. For example, increases in fuel efficiency were likely traded off for other things that drivers value (for example, acceleration speed and reliability). See NRC, *CAFE Report* at 3 (cited in note 10). One key strategy used by carmakers to increase fuel efficiency is the downsizing of cars, and many—but not all—members of the National Academy of Sciences' review committee believed that CAFE "probably resulted in an additional 1,300 to 2,600 traffic fatalities in 1993." Id. Two members dissented from that view, concluding that there may have been no effect on fatalities. Id at 3 n 2. Clearly, there are possible downsides and distortive effects of sticks. In this case, the existence of a CAFE stick could provide an additional argument for a countervailing innovation stick addressing car fatalities. See Part III.

129 See NRC, *CAFE Report* at 1 (cited in note 10) ("Congress requested that the National Academy of Sciences, in consultation with the Department of Transportation, conduct a study to evaluate the effectiveness and impacts of CAFE standards.").

economy for passenger cars had nearly doubled and that fuel economy for light trucks had improved by 50 percent since the CAFE standards were passed.[130] The two main contributors to this trend, the report concluded, were the CAFE standards and the price of gasoline in the 1970s, with the CAFE standards serving as a backstop for fuel economy when gasoline prices decreased in the 1990s.[131]

There is also empirical literature that speaks to how companies have met the challenges of the CAFE standards. Fuel efficiency can be increased in a variety of ways, which may be more or less innovation intensive. For example, companies may design smaller and lighter vehicles, as they did especially within the first decade of the CAFE standards.[132] Such redesigns may involve some innovation—for example, innovation in design or innovation that allows a firm to do things that others have done before it. Alternatively, it may involve simple uptake of existing knowledge once price signals have changed. Several analysts have suggested, however, that the CAFE program has induced important technological change.[133] Professor David Greene, in arguing that technological improvements were the key to fuel-economy improvements, has noted that a typical fifteen-mpg passenger car from 1975 equipped with the technology of the mid-1990s would get twenty-five mpg.[134] Technological progress was most rapid in the ten to fifteen years after the passage of the CAFE standards, which lends more support to the causal link between the CAFE standards and innovation.[135] A group of

130 See id at 14. See also David L. Greene, *Why CAFE Worked* *2 (Oak Ridge National Laboratory, Nov 6, 1997), archived at http://perma.cc/UQ2A-DS2S (noting that the average road vehicle in use in 1994 "emitted one-half to one-fourth as much pollution as the average vehicle in use in 1970" depending on which pollutant is measured).

131 See NRC, *CAFE Report* at 14–15 (cited in note 10). See also Greene, 11 Energy J at 37 (cited in note 113) (suggesting that CAFE standards "were perhaps twice as important an influence as gasoline prices").

132 See Hall, Note, 39 Transp L J at 9 (cited in note 113), citing David Sheridan, ed, *Increased Automobile Fuel Efficiency and Synthetic Fuels: Alternatives for Reducing Oil Imports* 105 (Office of Technology Assessment 1982).

133 See, for example, Greene, *Why CAFE Worked* at *8 (cited in note 130).

134 Id.

135 See Knittel, 101 Am Econ Rev at 3369 (cited in note 111). This finding is consistent with empirical work on other regulatory standards in the environmental area. See, for example, Richard G. Newell, Adam B. Jaffe, and Robert N. Stavins, *The Induced Innovation Hypothesis and Energy-Saving Technological Change*, 114 Q J Econ 941, 942–43 (1999) (finding "evidence that both energy prices and government regulations have affected the energy efficiency of the models of room air conditioners, central air conditioners, and gas water heaters available on the market over the last four decades").

Massachusetts Institute of Technology researchers has also concluded that to meet the recent increases in required fuel efficiency, the automobile industry will need to increase the deployment of existing technologies *and* shift the focus of future technological improvement to fuel economy (and away from, for example, increased performance).[136]

The CAFE program thus provides an example of a long-standing, consequential, and apparently partially effective innovation stick. Our analysis in Part I can help us understand why the program exists: greenhouse gas emissions represent a significant externality that is not incorporated into consumers' purchasing decisions. Without another intervention that could correct the market for pollution, car manufacturers face fewer incentives than is socially desirable to innovate to improve fuel economy.[137] Sticks may be preferred to carrots because the government perceives undercompensation to be a relatively small concern. After all, carrots are available for some inventions that would be relevant, such as new battery technologies. Other kinds of innovations—such as innovations in car design or corporate culture—may have few public-goods problems, because they may be cheap or unlikely to be afflicted by free riding problems. Regarding information costs, it is easy to define the group that will be penalized—the car industry—and that group is sufficiently sophisticated such that it can presumably contract out when it would be cost-effective. Our analysis also suggests, however, that the program might be still more effective if the agency were to take its "augural" conception further and deliberately depart from the directly foreseeable horizon of innovation, treating fines as the costs to be paid for failures to innovate at a faster pace.[138] After all, if we can model the social costs of pollution

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[136] See Parisa Bastani, John B. Heywood, and Chris Hope, *U.S. CAFE Standards: Potential for Meeting Light-Duty Vehicle Fuel Economy Targets, 2016-2025* *12 (MIT, Jan 2012), archived at http://perma.cc/97DC-VTKQ.

[137] We in no way mean to suggest that CAFE standards should be preferred to gas or carbon taxes; we point out only that in the absence of such tax increases, regulatory standards provide an alternative means to shape manufacturer incentives.

[138] This is especially so if we consider the standards of CAFE-style programs in other countries. The European Union and Japan both have regulatory programs like the CAFE program that are yet more ambitious in their requirements. See *Global Comparison of Passenger Car and Light-Commercial Vehicle Fuel Economy/GHG Emissions Standards* *5 (International Council on Clean Transportation, May 2014), archived at http://perma.cc/6B4K-5ZX3. Although standards are not easy to compare across countries, current standards in Japan appear to be only slightly lower than the CAFE standards projected in the new US regulations for 2025. See id. As we noted above, fuel economy

and if we have good data on the relative responsibility of the transportation sector, then such fines operate as incentives to improve and as de facto taxes that should help internalize the harms if the standards cannot be met. While political realities may lead the NHTSA (and Congress) to impose relatively modest demands on industry and not to push the innovation envelope via CAFE, a policy argument might be made for a more aggressive approach that more fully causes manufacturers to internalize the costs of their failures to innovate at the rates shown to be feasible by their peers.

The CAFE program (and California's analogous Zero Emission Vehicle mandate, which we analyze at length in the Appendix) may, on balance, be less desirable than a more systematic tax on carbon or even on more-sector-specific tax increases such as on gasoline. Carbon taxes and effluent taxes more generally can themselves be seen as a kind of innovation stick, albeit of a much more diffuse kind than those reviewed here. Given the political difficulties that such measures face in the United States, however, it is worth understanding the potential—and, indeed, historic—importance of regulatory innovation sticks in reducing the damage associated with our national overreliance on fossil fuels.

Notably, sticks have also been used in the environmental context to address other pollutants that might not be reached even by broad taxes on carbon or fuel. Sulfur dioxide (SO_2) emissions became a significant concern in the United States when the problem of acid rain was recognized in the 1970s.[139] The problem, which came primarily from power plants burning high-sulfur coal, was addressed with a cap-and-trade system in the Clean Air Act Amendments of 1990[140] ("the 1990 Amendments"). The law was designed to achieve a permanent overall reduction

is affected by many different factors, including the weight and performance of cars, so that carmakers serving the United States might nonetheless need to innovate to meet the same standard achieved in Japan if they attempt to keep closer to the profile of the average US fleet rather than simply move to the much smaller profile of the Japanese fleet. See Chyi-Ing Lin, Jer-Shiou Chiou, and Ben-Chieh Liu, *Product Quality, Gasoline Prices, and Japanese Shares in the U.S. Automobile Market*, 2 Intl J Bus 61, 81 n 2 (1997) (noting that Japanese cars' gas mileage exceeded that of American cars largely because the Japanese fleet size is smaller).

139 See James L. Regens and Robert W. Rycroft, *The Acid Rain Controversy* 35–58 (Pittsburgh 1988). Acid rain damages both plant life and aquatic life and has been a significant concern in the northeastern United States. See id at 48–51.

140 Pub L No 101-549, 104 Stat 2399, codified as amended in various sections of Titles 29 and 42.

in SO_2 emissions of about 50 percent from 1980s levels, phased in over time.[141] Allowances for existing power plants were established based on their historic emissions and were then scaled down to meet the overall target cap; plants were permitted to purchase allowances from other sources that outperformed their respective SO_2 caps.[142] The EPA tracked allowances by assigning a serial number to each allowance.[143] Fines for exceeding allowances were steep: $2,000 per ton, increasing with inflation, and a deduction of twice the amount of the excess from the allowance for the next year.[144] The Acid Rain Program is widely considered a success, resulting in 100 percent compliance,[145] much-reduced emissions,[146] and health and social benefits estimated in the tens of billions of dollars.[147]

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141 See Byron Swift, *How Environmental Laws Work: An Analysis of the Utility Sector's Response to Regulation of Nitrogen Oxides and Sulfur Dioxide under the Clean Air Act*, 14 Tulane Envir L J 309, 315 (2001). The 1990 Amendments began the phaseout in two stages. Phase I began in 1995 and affected coal-burning utility plants in twenty-one states. Phase II began in 2000 and targeted facilities in forty-seven states. See *2012 Progress Report: SO_2 and NO_X Emissions, Compliance, and Market Analyses* *2 (EPA), archived at http://perma.cc/6UYA-K7K8. In 2010, the 1990 Amendments capped SO_2 at half of its 1980 levels. Id at *1.

142 See 42 USC § 7651. See also Kanwalroop Kathy Dhanda, *A Market-Based Solution to Acid Rain: The Case of the Sulfur Dioxide (SO_2) Trading Program*, 18 J Pub Pol & Mktg 258, 259 (1999).

143 Dhanda, 18 J Pub Pol & Mktg at 260 (cited in note 142).

144 See id; 42 USC § 7651(j); 40 CFR § 77.6. The statutory penalty of $2,000 was "significantly higher" than the cost of an allowance. John Schakenbach, Robert Vollaro, and Reynaldo Forte, *Fundamentals of Successful Monitoring, Reporting, and Verification under a Cap-and-Trade Program*, 56 J Air & Waste Mgmt Assn 1576, 1578 (2006).

145 See *1999 Compliance Report: Acid Rain Program* *2 (EPA, July 2000), archived at http://perma.cc/6SPK-URXD. The program continued to achieve 100 percent compliance in 2009, the year before the statutory cap took effect. *Acid Rain and Related Programs: 2009 Emission, Compliance, and Market Analyses* *1 (EPA, Sept 2010), archived at http://perma.cc/BE46-NUFK.

146 See *Acid Rain and Related Programs* at *2 (cited in note 145); Swift, 14 Tulane Envir L J at 325–26 (cited in note 141); William L. Andreen, *Of Fables and Federalism: A Re-examination of the Historical Rationale for Federal Environmental Regulation*, 42 Envir L 627, 677–78 (2012) (noting that, between 1990—when the program was enacted—and 2005, emissions of hazardous air pollutants fell by about 40 percent).

147 See, for example, Lauraine G. Chestnut, *Human Health Benefits from Sulfate Reductions under Title IV of the 1990 Clean Air Act Amendments: Final Report* *6-4 (EPA, Nov 10, 1995), archived at http://perma.cc/H5LA-H9ES (finding the annual benefits of SO_2 reduction to be $10 billion in Phase I and projecting that they would rise to $40 billion by 2010); Conrad G. Schneider, *Death, Disease & Dirty Power: Mortality and Health Damage Due to Air Pollution from Power Plants* *5 (Clean Air Task Force, Oct 2000), archived at http://perma.cc/VV26-8ZS6 (disclosing that the total monetary benefits of bringing power plants up to modern pollution standards has been calculated at over $100 billion); Sophia Hamilton, *When Scientific Palmers Make Policy: The Impact and Future of Cap-and-Trade in the United States*, 4 J Bus, Entrepreneurship & L 269,

The 1990 Amendments established a carrot-and-stick mechanism: heavy fines created a new emissions baseline, and the trade provisions allowed those who could do better than the baseline to profit from that fact. As with the CAFE standards, firms could meet the new standard in a variety of ways. Retrospectively, it is clear that two main strategies were key to the early phase of SO_2 reductions: the use of scrubbers that reduced emissions from smokestacks and the more widespread use of lower-sulfur coal.[148] Scrubber technology improved significantly in this phase of the program after stagnating for decades—a result that has been attributed to the cap-and-trade program and the incentives it established for more-extensive scrubber use.[149] (Notably, the companies that manufacture scrubbers are not those directly affected by the cap.[150] As this illustrates, if contracting is easy, there is less pressure on the government's choice of the regulatory target.) While coal switching would seem to require less innovation, lower-sulfur coal had properties that made its industrial use difficult, so switching required both experimentation with new fuel blends and modifications to equipment—both of which were driven by the new standards.[151]

The stick aspect of the cap-and-trade model plays a similar role—it helps internalize the externalities associated with pollution. The SO_2 program also helps illustrate the potential of a cap-and-trade model that incorporates carrots to push the boundaries for pioneers as well as sticks to move the laggards along and change the structure of the market. The SO_2 program has been criticized as too permissive (that is, as having caps that are set too high),[152] reflecting the limits of government information about the cost of reductions in SO_2 and the social benefits

279 (2011) ("[T]he Acid Rain Program accounted for the largest quantified human health benefits of any major federal regulatory program implemented in the last ten years, with benefits exceeding costs by more than 40:1.").

148 Swift, 14 Tulane Envir L J at 328–29 (cited in note 141) (suggesting that scrubbers and low-sulfur coal were the main drivers for the reductions in Phase I). See also Renee Rico, *The U.S. Allowance Trading System for Sulfur Dioxide: An Update on Market Experience*, 5 Envir & Res Econ 115, 119 (1995) (covering Phases I and II).

149 See Swift, 14 Tulane Envir L J at 333–34 (cited in note 141). See also Allen S. Bellas, *Empirical Evidence of Advances in Scrubber Technology*, 20 Res & Energy Econ 327, 332 (1998) (noting that the SO_2 caps spurred innovation in scrubber technology by offering "improved incentives" to innovate).

150 See Swift, 14 Tulane Envir L J at 330–34 (cited in note 141).

151 See id at 336–37.

152 See, for example, id at 378; Curtis Carlson, et al, *Sulfur Dioxide Control by Electric Utilities: What Are the Gains from Trade?*, 108 J Polit Econ 1292, 1294–95 (2000).

associated with such reductions. Our analysis suggests that a yardstick model, which allows firms in competition to establish the appropriate levels of emissions reductions, might have been preferable because it would have added a dynamic dimension to emissions reductions that was absent in the statutorily chosen cap.[153]

All these examples are liability rules, but it is worth noting that property rules can also be deployed here. The government can act not only by imposing a fine on those who fail to innovate but also by simply banning a particular activity outright. Examples in the environmental domain are easy to come by. The Energy Independence and Security Act of 2007, by banning the manufacture of certain incandescent lightbulbs between forty and one hundred watts, created a stick backed by a property rule that "spurred innovation in the lighting industry."[154] Another successful example is provided by the United Nations Montreal Protocol on Substances That Deplete the Ozone Layer[155] ("Montreal Protocol"). Finalized in 1987, the Montreal Protocol banned the production of CFCs in all signatory countries by 2010.[156] The ban has been effective at the national level,[157] and it has spurred the rapid invention of CFC substitutes.[158]

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[153] Byron Swift has suggested that the government should have established a price floor for the allowance auctions. See Swift, 14 Tulane Envir L J at 380 n 348 (cited in note 141). Yardsticks might be implemented in a similar way, with reductions in allowances resulting from average prices that drop below a certain level.

[154] Stephen Lacey, *Republicans Set to Repeal Light Bulb Efficiency Standard That Would Save Consumers $12 Billion a Year* (Climate Progress, July 8, 2011), archived at http://perma.cc/YW3Z-CLP3.

[155] 26 ILM 1550 (1987) (Sept 16, 1987, entered into force Jan 1, 1989).

[156] See Guus J.M. Velders, et al, *Preserving Montreal Protocol Climate Benefits by Limiting HFCs*, 335 Science 922, 922 (stating that the Montreal Protocol is "responsible for global phaseout" of CFCs); Adjustments to the Montreal Protocol on Substances That Deplete the Ozone Layer Art 2A, 30 ILM 537, 539–40 (1991) (June 29, 1990, entered into force Jan 1, 1992).

[157] See K. Madhava Sarma, *Compliance with the Montreal Protocol* *308 (Seventh International Conference on Environmental Compliance and Enforcement), archived at http://perma.cc/34NN-LHER (noting that only thirty-five countries failed to comply with the Montreal Protocol and that they did so by exceeding the cap by relatively low amounts). At the international level, compliance has been "nearly perfect." Cass R. Sunstein, *Of Montreal and Kyoto: A Tale of Two Protocols*, 31 Harv Envir L Rev 1, 38 (2007).

[158] See Klaus Rennings, *Redefining Innovation — Eco-innovation Research and the Contribution from Ecological Economics*, 32 Ecological Econ 319, 328 (2000). Some of these substitutes have been successful, while others have generated their own harms and have been the subject of further bans. Industries began producing alternatives, some of which have generated environmental concerns of their own—for example, because they contribute to climate change. See Timo Goeschl and Grischa Perino, *Innovation without Magic Bullets: Stock Pollution and R&D Sequences*, 54 J Envir Econ & Mgmt

2. Medicare's diagnosis-related groups.

Another example of using potential penalties to incentivize producer innovation is Medicare's hospital reimbursement scheme for inpatient care, in which physicians classify patient types into Medicare-established diagnosis-related groups (DRGs).[159] Under the DRG system, Medicare reimburses hospitals an amount per patient determined in part by the average cost nationally of treating patients with the same DRG assignments. Specifically, the reimbursement amount is determined by adjusting a standardized base payment for operating and capital costs based on a DRG weight—a relative value assigned to each DRG that represents the average resource intensity of cases within the DRG.[160] These values are derived from national data and updated annually. The base reimbursement amount is also adjusted according to local-level conditions, including wage index, cost of living, proportion of low-income patients served by the hospital, and costly "outlier" cases.[161]

This reimbursement model produces a kind of yardstick incentive with both carrots and sticks.[162] Hospitals are incentivized to reduce patient costs while increasing the volume of patients.[163] If hospitals lower treatment costs below the reimbursement amount, they profit. By the same token, if hospitals' treatment costs are above the DRG reimbursement amount, they face losses.[164] Thus, hospitals competing against the yardstick of average national costs are incentivized to implement technology and process innovations to produce more cost-effective care.[165] Hospitals may consider cost trade-offs; for instance, they

146, 156 (2007). Regulators have sought to adapt by, for example, targeting these newer pollutants in other environmental protocols such as the Kyoto Protocol. Id.

159 See Centers for Medicare & Medicaid Services, *Acute Care Hospital Inpatient Prospective Payment System: Payment System Fact Sheet Series* *2 (Department of Health and Human Services, Apr 2013), archived at http://perma.cc/V3A3-CXL8.

160 See id at *3.

161 Id.

162 See, for example, Shleifer, 16 Rand J Econ at 320 (cited in note 21).

163 See Francesc Cots, et al, *DRG-Based Hospital Payment: Intended and Unintended Consequences*, in Reinhard Busse, et al, eds, *Diagnosis-Related Groups in Europe: Moving towards Transparency, Efficiency and Quality in Hospitals* 75, 82 (Open University 2011).

164 See Shleifer, 16 Rand J Econ at 319 (cited in note 21); Cots, et al, *DRG-Based Hospital Payment* at 86 (cited in note 163).

165 See Cots, et al, *DRG-Based Hospital Payment* at 81–82 (cited in note 163).

might use high-cost antibiotics to reduce the length of a patient's stay, which can save on overall costs.[166]

Again, our theoretical analysis makes available a fairly simple explanation for why a yardstick carrot-and-stick model was adopted here. Because of the commitment that the government has made to cover certain medical expenses, the difficulty that governments have in directly observing the quality of care, and the lack of information about and cost-internalization by patients, some cost discipline is needed. Some of the innovations associated with patient care may generate concerns about undercompensation, but patents will be available for some of these (such as new technologies, new treatments, or better software to manage patient data). Other innovations are likely more social in nature—better forms of communication in the hospital, for example. These DRG regulations allow the government to remain agnostic about the best methods of reducing Medicare costs. Individual hospitals are allowed discretion to pursue the types of interventions and innovations that will make their treatments most cost-effective. Moreover, the hospitals competing against the average annual yardstick will understand that the average is likely to be a moving target as hospitals producing at the average can increase their profits by reducing their costs of care. The yardstick combination of carrots and sticks thus not only incentivizes cost laggards to reduce their costs to the national average but also incentivizes leaders in cost-effectiveness to continue to improve.

The DRG example also illustrates the information problems associated with sticks and nontraditional carrots. There is a real concern that the DRG yardstick mechanism can also distort incentives on certain margins. Hospitals may develop strategies to reduce the consumption of resources by reducing lengths of stays without improving treatment, by increasing hospital admissions for profitable patients, or perhaps by not implementing better practices or technologies in favor of cost savings.[167] In addition, hospitals may "upcode" patients to diagnostic categories that generate larger reimbursements.[168] Whether these incentive

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166 See id at 83–85.

167 See id at 83. See also *Diagnosis Related Groups (DRGs) and the Medicare Program: Implications for Medical Technology; A Technical Memorandum* 25 (Office of Technology Assessment 1983).

168 Leemore S. Dafny, *How Do Hospitals Respond to Price Changes?*, 95 Am Econ Rev 1525, 1526 (2005). See also Cots, et al, *DRG-Based Hospital Payment* at 89 (cited in note 163).

distortions outweigh the yardstick benefits derived above is beyond the scope of this Article. But the DRG reimbursement scheme represents another example of an innovation stick already in use, this time deployed in conjunction with carrots, via the yardstick approach.

B. State Penalties

While the last Section focused on producer-directed incentives, it is also possible to structure innovation sticks to potentially penalize government entities whose actions impact the rate of innovation. Here we discuss two federal regulations that have subjected states to potential innovation-stick penalties.

1. Maximum–speed limit penalties.

In 1974, in response to the Organization of the Petroleum Exporting Countries oil crisis, Congress passed the National Maximum Speed Law as § 2 of the Emergency Highway Energy Conservation Act,[169] mandating a speed limit of fifty-five miles per hour (mph) on all interstate roads.[170] Soon after, Congress adopted the Federal-Aid Highway Amendments of 1974,[171] which made the approval of highway projects funded by federal funds contingent on state-enforcement certification.[172] Although the national speed limit was enacted to conserve fuel, road fatalities fell by a startling 16 percent the very first year after the limit was imposed, from 54,052 to 45,196.[173]

However, many states openly resisted complying with the maximum speed limit. In response to this lack of compliance, Congress passed the Federal-Aid Highway Act of 1978,[174] which incentivized states to abide by the maximum speed limit by

169 Pub L No 93-239, 87 Stat 1046, 1046–47 (1974), codified at 23 USC § 154 (1974), repealed by National Highway System Designation Act of 1995 § 205(d)(1)(B), Pub L No 104-59, 109 Stat 568, 577.

170 See Federal Highway Administration, *Speed Monitoring Program Procedural Manual for the National Maximum Speed Limit* I-1 (DOT 1980) ("Speed Limit Manual") (explaining that the fifty-five-mph speed limit was initially a temporary measure imposed as a result of the severe fuel shortage in late 1973); Lee S. Friedman, Donald Hedeker, and Elihu D. Richter, *Long-Term Effects of Repealing the National Maximum Speed Limit in the United States*, 99 Am J Pub Health 1626, 1626 (2009).

171 Pub L No 93-643, 88 Stat 2281 (1975), codified as amended in various sections of Title 23.

172 FHWA, *Speed Limit Manual* at I-1 (cited in note 170).

173 Friedman, Hedeker, and Richter, 99 Am J Pub Health at 1626 (cited in note 170).

174 Pub L No 95-599, 92 Stat 2689.

withholding federal highway funds for noncompliance and awarding grants for compliance.[175] Federal legislation required states to provide data—such as the percentage of vehicles that exceeded fifty-five mph—to the Federal Highway Administration (FHWA).[176] States collected these data by utilizing monitoring stations that recorded the speeds of passing vehicles during set observation periods.[177]

The federal statute conditioned the amounts of sanctions and grants on the results of the speed-monitoring audits. Like a proposed tobacco look-back provision discussed in the Appendix,[178] which conditioned penalties on the results of youth-smoking surveys, the Federal-Aid Highway Act conditioned funds on the results of passing-vehicle-speed surveys. In 1979, if more than 70 percent of surveyed vehicles in a state exceeded fifty-five mph, the federal government withheld 5 percent of the state's highway funds; if less than 60 percent of surveyed vehicles exceeded fifty-five mph, the state received a boost of 10 percent in federal-aid highway funds.[179] The statutory level of speed limit compliance for sanctions and grants fell by 10 percent every year until 1983, at which point a state lost 10 percent of federal highway funds if more than 30 percent of its surveyed motorists exceeded the maximum speed limit and gained an additional 10 percent grant if less than 20 percent of its surveyed drivers exceeded the fifty-five-mph speed limit.[180]

While not based on an evolving yardstick as with Medicare DRG compensation,[181] the Federal-Aid Highway Act regime did represent a combination of carrots and sticks that became more stringent over time. The potential penalties represented another example of innovation sticks that might this time be described as attempts to make more salient for states certain social costs that they have the power to affect but that perhaps are insufficiently salient to state officials (or local voters) to be addressed locally.[182] States that were lagging behind the compliance standard were given financial incentives to take action to come into

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175 FHWA, *Speed Limit Manual* at I-1 (cited in note 170).

176 Id at VI-1.

177 Id at IV-3 to -5.

178 See Appendix at Part II.B.

179 FHWA, *Speed Limit Manual* at I-3 (cited in note 170).

180 Id.

181 See Part II.A.2.

182 In contrast, the federal NHTSA apparatus for collecting, reporting, and analyzing fatality data might make highway-safety issues more salient to federal officials.

compliance. And as with our other examples, these incentives were not tied to taking any particular course of action. A state was free to choose the regulatory technology that it expected would be best suited to avoiding the increasingly stringent penalties for noncompliance. Again, this serves as a reasonable domain for a stick given the actors that are targeted (states) and the multimodality of the innovations that we anticipate would help. Undercompensation here would also appear to be a relatively small risk, with traditional carrots in the background to help prevent free riding on new technologies (such as speed cameras) that the new regulations might help incentivize, as well as many possible inexpensive measures—perhaps amounting more to adoption than to innovation—that might be deployed by states to reduce speeding rates.

This increasing stringency may, however, have eroded the political viability of the statute.[183] In 1987, Congress permitted states to increase speed limits on rural interstate highways to sixty-five mph.[184] A study by the Insurance Institute for Highway Safety (IIHS) found that fatalities on rural interstates increased between 25 percent and 30 percent when states began increasing speed limits on rural highways.[185] Despite the relaxation in regulation, the maximum–speed limit law remained unpopular,[186] and in 1995, Congress repealed the maximum speed limit, allowing states to set their own speed limits for the first time in more than two decades.[187] This effectively ended the era of carrot-and-stick incentives. Although national traffic fatalities have remained relatively stable since the repeal of the maximum–speed limit law, many have argued that the number of fatalities caused by increased speed has been offset by improvements in vehicle safety.[188] One study concluded that increased speed limits caused 12,545 deaths between the years 1995 and 2005.[189]

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183 Consider *Speed: Speeding Makes Crashes More Likely and More Likely to Be Deadly* (Insurance Institute for Highway Safety, July 2014) ("Speed Limit Q&As"), archived at http://perma.cc/5LBQ-QY9N (noting that after imposing stringent maximum speed limits, Congress later lowered these limits).

184 Id.

185 Id.

186 See Associated Press, *Lawmakers Agree on Measure to End National Speed Limit* (LA Times, Nov 16, 1995), archived at http://perma.cc/GY5R-AF4U.

187 *Speed Limit Q&As* (cited in note 183).

188 See *National Maximum Speed Limit Repeal: Ten Years Later; Increasing Speeds Have Limited Highway Safety Progress* (Governors Highway Safety Association, Dec 6, 2005), archived at http://perma.cc/D475-9DWU.

189 Friedman, Hedeker, and Richter, 99 Am J Pub Health at 1628 (cited in note 170).

2. No Child Left Behind.

NCLB represents an additional example of innovation sticks directed at government entities—in this case, public schools.[190] NCLB was structured to use federal funding to states to assist and enhance elementary and secondary school education throughout the country. As provided, the law's aim is to close the achievement gap by ensuring that every student is proficient in reading and math by 2014.[191] The single largest source of funding, Title I,[192] makes funds available specifically for economically disadvantaged students.[193] At the core of Title I's funding provisions is academic accountability: states that accept federal funds must establish uniform "challenging academic standards" for public schools in the state and administer annual standardized exams to test whether students are meeting those standards.[194]

Title I is enforced by what amounts to failure-to-innovate penalties directed both at failing schools and at failing school districts.[195] Specifically, the law imposes increasingly harsh sanctions on schools that do not make "adequate yearly progress" (AYP) as determined by test scores.[196] If students fail to meet the standards for two consecutive years, the school must implement a two-year improvement plan.[197] Further, the school's students may opt to attend a different public school, or a charter school, within the same district.[198] After three consecutive years of failure to

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[190] See, for example, 20 USC § 6311(b)(2)(A)(iii); Office of the General Counsel, *Closing the Achievement Gap: The Impact of Standards-Based Education Reform on Student Performance* *30 (US Commission on Civil Rights, July 2, 2004), archived at http://perma.cc/RW5R-2HA4; Office of the Under Secretary, *No Child Left Behind: A Desktop Reference; 2002* *10 (Department of Education, Sept 2002) ("Desktop Reference"), archived at http://perma.cc/EUX2-BHZG.

[191] See 20 USC § 6311(b)(1)(C), (2)(F).

[192] See 20 USC §§ 6331–39.

[193] See OUS, *Desktop Reference* at *13 (cited in note 190). See also James E. Ryan, *The Perverse Incentives of the No Child Left Behind Act*, 79 NYU L Rev 932, 937 (2004) (explaining that Title I was the government's largest educational-aid program).

[194] 20 USC § 6311(b)(1). See also Ryan, 79 NYU L Rev at 932–33 (cited in note 193).

[195] Experts have criticized this sanctions-based approach for not properly equipping schools with the resources needed to improve. See, for example, Robert Manwaring, *Restructuring 'Restructuring': Improving Interventions for Low-Performing Schools and Districts* *2 (Education Sector, Apr 2010), archived at http://perma.cc/SDN2-ZFZ5.

[196] As with CAFE standards, AYP is less about ensuring that schools improve vis-à-vis past performances than it is about meeting uniform yardsticks, which are applicable to all schools. See Ryan, 79 NYU L Rev at 941 (cited in note 193).

[197] 20 USC § 6316(b)(1)(A).

[198] 20 USC § 6316(b)(1)(E)(i).

make AYP, the school must provide students with outside tutoring services.[199] A school that fails for four years in a row must make further corrective changes, such as hiring new staff or implementing a new curriculum.[200] And after five years of not making AYP, the school is placed on "restructuring" status and must cede control to the state, which then may convert the school into a charter school or hire a private company to manage it.[201]

As with our other examples, Congress designed the NCLB incentives to be technology agnostic.[202] Specifically, states have broad flexibility in determining how to prepare students for these tests.[203] Indeed, according the US Department of Education, a hallmark of NCLB is to provide increased flexibility and local control.[204]

By the 2008–2009 school year, 4,580 Title I schools out of approximately 47,000 nationwide were in the restructuring phase.[205] Three-quarters of these schools opted for personnel-neutral reforms such as implementing new grading policies or curricula.[206] With respect to school districts, by the 2008–2009 school year, 1,735 districts out of roughly 15,000 required "corrective action," the intermediate level of sanctions.[207] As with the schools faced with restructuring, over 75 percent did not replace personnel but rather took other corrective actions such as changing their curricula or allowing students to transfer to other districts.[208] In some instances, NCLB sanctions have led to school closures; in

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199 20 USC § 6316(b)(5)(B).

200 20 USC § 6316(b)(7)(C)(iv).

201 20 USC § 6316(b)(8).

202 See 20 USC § 6311(b)(2) (omitting technology-based subjects from the statutory language). See also Wayne C. Riddle, *Adequate Yearly Progress (AYP): Might Growth Models Be Allowed under the No Child Left Behind Act?* *5 (Congressional Research Service, Dec 1, 2005), archived at http://perma.cc/U3D4-3YA8 (noting that AYP standards focus primarily on reading and math achievement). Many have criticized NCLB as providing incentivizes to states to implement lower educational standards that are easier to meet. See, for example, Ryan, 79 NYU L Rev at 940–42 (cited in note 193).

203 See *Horne v Flores*, 557 US 433, 461 (2009) ("[NCLB] reflects Congress' judgment that the best way to raise the level of education nationwide is by granting state and local officials flexibility to develop and implement educational programs that address local needs, while holding them accountable for the results."). States also have discretion to define their own proficiency standards as well as AYP benchmarks that measure "progress toward the attainment of those standards." Id.

204 See OUS, *Desktop Reference* at *10 (cited in note 190).

205 Manwaring, *Restructuring 'Restructuring'* at *2 (cited in note 195).

206 See id at *3–4.

207 Id at *6.

208 See id.

the 2007–2008 school year, approximately 3 percent of schools that had to restructure under the law opted to close down.[209]

In September 2011, President Obama announced that his administration would waive many of the components of NCLB, including the provisions requiring 100 percent proficiency in math and reading by 2014 and the increasingly stringent sanctions for failures to make AYP.[210] As of February 2015, the administration had granted waivers to the District of Columbia, Puerto Rico, and forty-three of the forty-five states that had applied.[211] In one sense, these waivers can be interpreted as the effective end of innovation sticks. The waivers give states so much more flexibility in setting the agenda for academic improvement (such as by implementing standards that focus on achievement growth rather than absolute achievement) that they can reduce the chance that they will fail their own chosen standards. However, another interpretation suggests that a diminished credible threat of sanctions, especially for Title I schools, remains in place: the lowest-performing schools must take the most-severe remedial actions.[212]

Stepping back, we acknowledge that our experience with innovation penalties in these examples (and the additional ones discussed in our Appendix) has been at best a mixed success. Some of the threatened sticks have not been sustained over time. The maximum–speed limit penalties were ultimately rescinded after a few years. The NCLB-triggering conditions have been substantially diluted, and current debates over the future of NCLB suggest broad dissatisfaction with its approach.[213] But the CAFE and DRG regulations have been more sustainable and, at least arguably, successful in inducing affirmative incentives to improve welfare and push the envelope of human knowledge.

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209 Manwaring, *Restructuring 'Restructuring'* at *3 (cited in note 195).

210 Sam Dillon, *Obama Turns Some Powers of Education Back to States* (NY Times, Sept 23, 2011), archived at http://perma.cc/2U7K-QNSR; *No Child Left Behind - Overview* (New America Foundation, Apr 24, 2014), archived at http://perma.cc/5ZVA-3B82.

211 *ESEA Flexibility* (Department of Education, Feb 25, 2015), archived at http://perma.cc/5WEQ-GKLP.

212 See Wayne Riddle, *Major Accountability Themes of Second-Round State Applications for NCLB Waivers* *3 (Center on Education Policy, May 2012), archived at http://perma.cc/9NKC-XX47.

213 See Richard D. Kahlenberg, *Saving School Choice without Undermining Poor Communities* (The Atlantic, Feb 14, 2015), archived at http://perma.cc/MHY3-9FZ9.

All in all, the experience with innovation penalties suggests that the government faces nontrivial problems both in establishing the appropriate innovation goals that would avoid imposition of penalties and in credibly following through and imposing penalties on those that fail to meet the goals. The yardstick version of innovation sticks responds to both of these concerns. A yardstick trigger for penalties set at the median success rate is agnostic to the pace of progress. The government need not augur as to what will be feasible but instead need only look at what the median was able to achieve. Moreover, a median trigger builds in a natural, sizable constituency—the 50 percent that avoided the penalty—to lobby for the ex post imposition of the penalty. From this perspective, it might not be surprising that the DRG implementation and, to some extent, the CAFE standards (which have been careful not to move beyond what half of the industry could accomplish) have been two of the more successfully sustained programs. But the purpose of this Section has not been to argue that these specific innovation penalties are ideally designed or that they are the best approach in each circumstance. The purpose has instead been to offer examples that show that innovation sticks are not merely a theoretical possibility but are already in use, and are being used in domains that our theoretical analysis can help explain.

III. A CAFE STANDARD FOR AUTOMOBILE FATALITIES

In this Part, we provide empirical support for the idea that CAFE-like incentives could reduce the prevalence of automobile fatalities, which annually claim the lives of more than thirty thousand people.[214] More specifically, we imagine a world in which manufacturers are penalized if their fleets produce above-median fatality rates and states are penalized if drivers in their jurisdictions produce above-median fatality rates. Our aim here is to illustrate how the concept of innovation sticks—and more particularly, a yardstick approach—might be applied to a new problem. We have chosen the problem of car fatalities both because it is socially important and because existing regulatory efforts—such as mandated recalls, technology-forcing safety standards,

214 US Census Bureau, *Statistical Abstract of the United States: 2012* *693 (Department of Commerce), archived at http://perma.cc/6K79-BV2A (calculating that the number of traffic fatalities in the United States in 2009 was greater than thirty thousand).

and safety-rating disclosures—have been disappointing. As summarized by Professors Jerry Mashaw and David Harfst:

> Forced to choose between pursuing its technology-forcing mission, and accommodating the demands of the hostile legal culture surrounding it, NHTSA has adapted by evolving forms of regulation and non-regulatory "collaboration" that have less to do with driving innovation than avoiding conflict.[215]

The problem of automobile fatalities is a particularly attractive domain for sticks because, in accord with our theoretical account, it is plausibly subject to both externalities and diverse modes of innovation. Moreover, the high sunk costs of automobile manufacturing make it relatively unlikely that undercompensation will induce industry exit. Yardstick carrots (providing rewards for below-median-fatality manufacturers) might also be effective at spurring the desired safety improvements. But a system of purely yardstick carrots would require the ongoing collection of tax dollars to fund the annual rewards. Our yardstick-fatality proposal, in contrast, is revenue neutral and combines carrot and stick incentives by transferring the stick revenues from the above-median-fatalities laggards to the below-median-fatalities pioneers.[216] This reward would be in addition to any patent a pioneer is able to secure for a nonobvious improvement in the safety prior art, illustrating the combined potential of carrots and traditional sticks: sticks can correct market incentives and encourage laggards while traditional carrots can help prevent undercompensation.

The use of a yardstick standard not only is less susceptible to regulatory capture but also avoids the evidentiary requirements that courts have demanded in advance of technology-forcing safety standards. For example, in *PACCAR, Inc v National Highway Traffic Safety Administration*,[217] the Ninth Circuit, in striking down an NHTSA antilock-brake safety

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215 Jerry L. Mashaw and David L. Harfst, *The Transformation of Auto Safety Regulation: Bureaucratic Adaptation to Legal Culture* *1–2 (unpublished manuscript, Nov 25, 2015) (on file with authors). See also Jerry L. Mashaw and David L. Harfst, *The Struggle for Auto Safety* 111 (Harvard 1990) (noting a shift in automobile-safety regulation "from science and planning to crime and punishment").

216 The rewards could be made proportional to the amount by which the pioneer was below the median.

217 573 F2d 632 (9th Cir 1978).

standard, found that "more [probative] and convincing data evidencing the reliability and safety of vehicles that are equipped with antilock and in use must be available before the agency can enforce a standard requiring its installation."[218] Under a yardstick measure, the "practicable" requirement would be self-established by the demonstrated success of competitor peers.[219]

We begin by identifying particular manufacturers and states that persistently lag behind their peers, providing an empirical basis for thinking that innovation—whether social or technological—is both needed and possible in this area. As we show in Figures 2 and 5, manufacturers like Pontiac and Mitsubishi persistently subject their own drivers and others to an above-median risk of death, while some states, like Mississippi and Arkansas, persistently subject their own drivers and others to an increased risk of death.[220] While there have been continual improvements in automobile safety over time, we identify the savings in lives that might be achieved if the laggard states and manufacturers were brought to the median safety rates of their peers.[221] While CAFE has used an augural process of goal setting

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[218] Id at 643.

[219] Id at 635 & n 5. Mashaw and Harfst have independently considered whether an even more aggressive form of yardstick competition might better incentivize safety laggards to catch up. See Mashaw and Harfst, *The Transformation of Auto Safety Regulation* at *67 (cited in note 215):

> In our own reflections over the years, we have sometimes wondered why NHTSA did not seek to advance safety innovation by proposing regulations that would in effect require all manufacturers to match the safety performance of the top performers – the top decile or quartile of industry. Perhaps the combination of something like the [New Car Assessment Program (NCAP)] program, incentivizing some number of manufacturers to up their safety game, (our research thus far has not established that NCAP as presently constituted has actually had that effect) coupled with rules codifying industry practice that force laggard companies to "catch up", begins to resemble such a regime.

See also 42 USC § 7412(c)–(d) (requiring that existing sources of certain hazardous air pollutants meet the emission-control level achieved by the top 12 percent of the relevant industry group's currently operating sources). Alternatively, policymakers might choose a less aggressive percentile trigger. For example, penalizing only the least successful quintile of producers might increase the political feasibility of a yardstick by reducing the proportion of industry members that are subject to the penalty. Or yardsticks could be made less aggressive by punishing members who were unable to meet some peer percentile after a lag or who failed to make preestablished progress over time toward the peer-percentile target.

[220] We shared an early draft of this Article with manufacturers and states whom we identified as persistent laggards; we profited from private communications with some that responded.

[221] Our choice to use the median US fatality rate is in many ways conservative, as many other developed nations have shown that it is possible to generate substantially

that has been negotiated in concert with car manufacturers, our simulations imagine a yardstick trigger for penalties set at the median fatality rate. The yardstick median is less susceptible to negotiation failure ex ante and, as we argued before, provides a more credible threat of enforcement ex post.[222]

Financial incentives to encourage laggards to innovate toward the median currently achieved by others—even if only partially effective—might save tens of billions of dollars in loss of life. We present our estimated savings as a heuristic upper bound, because we acknowledge that penalizing failures to innovate is unlikely to eliminate all above-median fatalities. Then again, fines for above-median fatality rates create new incentives for manufacturers and states that are currently at or just below the median fatality rate to innovate to stay ahead of the game. This new competition to stay ahead of the median—and thus qualify to share in the transfer of the above-median penalties—might lead to an acceleration of innovation and the diffusion of innovation throughout the industry and the states. As a matter of theory, innovation sticks could produce benefits even larger than the upper-bound estimates suggested here.

A. Yardstick Penalties for Above-Median Manufacturers

To begin, Figure 1 shows, using NHTSA Fatality Analysis Reporting System data from 2000 to 2011, the median manufacturer fatality rates per 100,000 registered vehicles for two different fatality measures, which we refer to as "total" fatalities and "external" fatalities.[223] "Internal" fatalities are fatalities of

lower fatality rates. For example, the World Health Organization estimated in 2013 that the road-traffic-death rate per 100,000 population was 67 percent lower in the United Kingdom (and 40 percent lower in Canada) than in the United States. *Global Status Report on Road Safety 2013: Supporting a Decade of Action* *244–51 (World Health Organization, 2013), archived at http://perma.cc/9V2M-GU4L.

222 See Part I.C.

223 These measures intentionally double count certain types of fatalities in multiple-car accidents. If a Toyota and a GMC are involved in an accident in which a person in the Toyota dies and a pedestrian dies, the data will attribute to Toyota two total fatalities and one "external pedestrian" fatality, while they will attribute to GMC two total fatalities, one "external pedestrian" fatality, and one "external in-other-car" fatality. This double counting is appropriate for policy purposes because it captures what Professor Robert Cooter has called the "double responsibility at the margin." Robert Cooter, *Unity in Tort, Contract, and Property: The Model of Precaution*, 73 Cal L Rev 1, 4 (1985). In our example, because both the Toyota and the GMC cars were involved in the "production" of the accident, both are appropriate targets of policies attempting to internalize the costs of excessive fatalities.

persons inside any car involved in an accident with at least one fatality. External fatalities include "external pedestrian" fatalities and "external-in-other-car" fatalities.

FIGURE 1. MEDIAN MANUFACTURER FATALITY RATES[224]

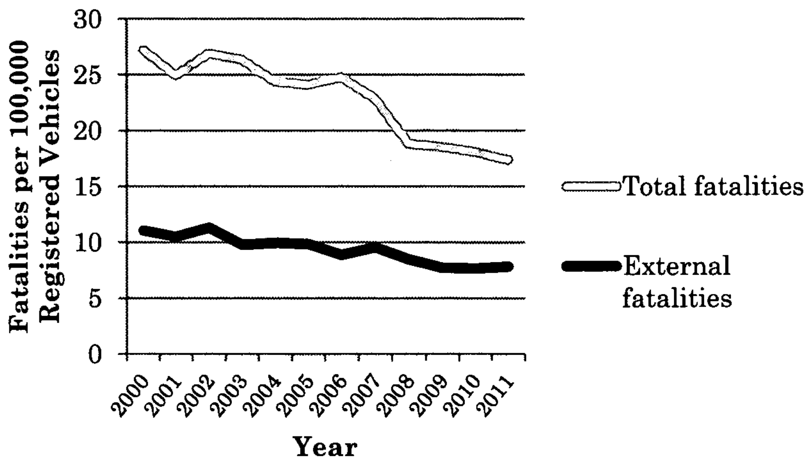
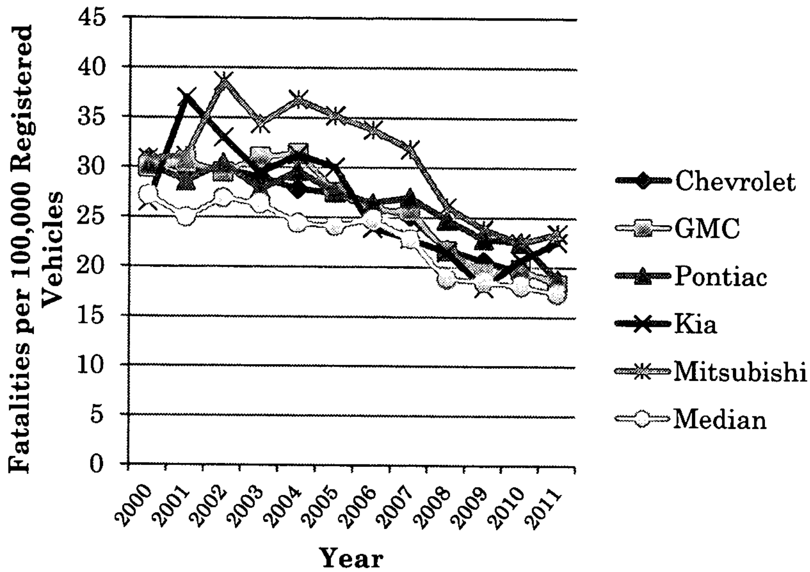


Figure 1 shows increasing safety standards over time measured in both the "total" and "external" fatality rates. The median manufacturer total-fatality rate declined from 26 fatalities per 100,000 registered vehicles in the early years of this century to a rate of fewer than 18 fatalities per 100,000 registered vehicles in 2011. But there is a marked dispersion in the safety of cars produced across manufacturers. Figure 2 plots the fatality rates of the five manufacturers who averaged the highest total-fatality rates across this time period; it shows that Chevrolet, GMC, Pontiac, Kia, and Mitsubishi cars experienced total-fatality rates that were persistently higher than the median fatality rates for the industry.

224 These fatality data are from NHTSA's Fatality Analysis Reporting System. The total number of registered vehicles is from the FHWA. National-fleet proportion data are from the FHWA's National Household Travel Survey (NHTS) on the years from 2001 until 2009. The graph shows a weighted median of 36 passenger-vehicle manufacturers' fatality rates per 100,000 registered vehicles, in which the weight is the manufacturer's national-fleet proportion.

FIGURE 2. TOTAL-FATALITY RATES OVER TIME[225]



Of course, manufacturers compete to some extent on the safety of their automobiles. Hence, manufacturers already have some incentive to reduce the likelihood that their cars will kill people—and especially people inside their cars. But studies suggest that the government's crash-test system provides imperfect information about real-world safety risks; these studies also indicate that consumers are imperfectly informed about safety ratings and that they imperfectly react to safety information.[226]

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225 Figure 2 plots the five manufacturers with the highest fatality rates over time and the median fatality rates for 2000 through 2011. Total fatality numbers are the total numbers of fatalities in crashes involving that manufacturer.

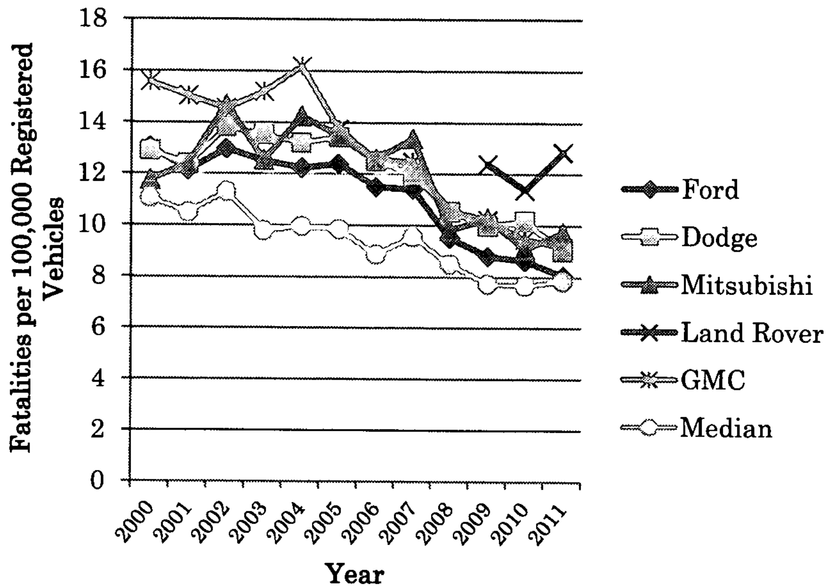
226 See, for example, David W. Harless and George E. Hoffer, *Do Laboratory Frontal Crash Test Programs Predict Driver Fatality Risk? Evidence from within Vehicle Line Variation in Test Ratings*, 39 Accident Analysis & Prevention 902, 909–10 (2007) (suggesting that crash tests have no predictive value with respect to light trucks, vans, minivans, and SUVs, and providing that cars with one-star ratings performed twice as well as cars with two-star ratings). See also Stephen W. Pruitt and George E. Hoffer, *Crash Test Dummies? The Impact of Televised Automotive Crash Tests on Vehicle Sales and Securities Markets*, 23 J Pub Pol & Mktg 102, 106 (2004) (finding no evidence that NBC Dateline broadcasts of IIHS crash testing affect consumer purchases or manufacturer stock prices, even though IIHS ratings are significantly correlated with injury claims reported by the Highway Loss Data Institute); George E. Hoffer, Stephen W. Pruitt, and Robert J. Reilly, *Market Responses to Publicly-Provided Information: The Case of Automotive Safety*, 24 Applied Econ 661, 664 (1992) (finding no effect on sales of cars with excellent or poor ratings).

But even those who are more sanguine about consumers' abilities to make informed decisions about their own safety should still be concerned about manufacturers who systematically lag behind in protecting people outside their customers' cars. Manufacturers have imperfect incentives to reduce the fatalities of people outside their cars, as they are usually not liable when the automobiles they produce are involved in accidents—the same is true for the drivers themselves (and the drivers' insurance companies).[227] The manufacturers who are "total fatality" laggards are detrimental to society from a public health perspective.

Accordingly, Figure 3 plots the fatality rates of the five manufacturers who averaged the highest external-fatality rates across this time period. The external-fatality rate is calculated by looking at each car involved in an accident in which there is a fatality and determining whether a fatality from someone not inside the car is being considered. For example, if two Toyotas are involved in an accident that kills the driver of one of the cars, that accident would increase Toyota's external fatalities by one (and Toyota's total fatalities by two). Figure 3 shows that Ford, Dodge, Mitsubishi, Land Rover, and GMC cars experienced external-fatality rates that were persistently higher than the median external-fatality rates for the industry.

[227] For the manufacturers, this is an outgrowth of the difficulty of reaching failures to innovate through tort liability, as discussed above. Insurance companies have no incentives to price into their products fatality risks that the companies are not legally required to pay. Insurance covers only accidents in which fault is present, rather than all accidents. This policy, as well as caps on liability, means that while insurance companies do have some incentive to learn of and price in risks associated with riskier cars, these incentives are highly incomplete.

FIGURE 3. EXTERNAL-FATALITY RATES OVER TIME[228]



The persistently elevated fleet fatality rates of particular manufacturers displayed in Figures 2 and 3 motivate us to ask what the impact on fatalities would be if CAFE-like penalties succeeded at inducing above-median manufacturers to take actions to reduce their fatality rates down to the median. These penalties would be a kind of innovation stick—but of a less aggressive kind, because they would not require manufacturers to innovate toward a level of achievement currently outside the existing realm of possibility. The penalties would ask manufacturers to achieve only the type of safety currently achieved by the median registered car.

Table 2 takes up this challenge by asking how many lives would have been saved on average annually if the intervention succeeded at merely reducing the fatality rates of above-median manufacturers down to the median industry rate.[229] We take this

[228] Figure 3 plots the five manufacturers with the highest average median external-fatality rates from 2000 through 2011. Land Rover appears only from 2009 through 2011 because the manufacturer was not present in the NHTS's sample until 2009.

[229] We deflate the numbers to adjust for the double counting mentioned above. See note 223. This ensures that these estimates of lives lost and social costs (here and below) are not inflated by the double counting. We create a total number of fatalities over median by summing the fatalities over median for each manufacturer. However, because each manufacturer's number involves double counting, we multiply this fatalities-over-median

analysis to likely be an upper-bound estimate of the potential savings from a CAFE-like yardstick penalty. As noted above, it may be beyond the practicable control of some manufacturers to lower the fatality rates, or other manufacturers may lower their rates by shifting high-risk drivers to their heretofore below-median competitors. It is theoretically possible, though, that yardstick competition might produce even faster declines in the industry median rate as below-average manufacturers take additional precautions to assure that they stay below the penalty-inducing median fatality rate.

TABLE 2. ABOVE-MEDIAN ANALYSIS[230]

	Fatalities over Median	Proportion of Fatalities over Median (%)	Yearly Cost of Fatalities over Median ($ billion)
Total Fatalities	1690	4.8	12.9
External Fatalities	920	7.1	7.0

As shown in Table 2, moving laggard manufacturers to the median fatality rates might save close to 1,700 lives annually, a number that represents close to 5 percent of all car fatalities.

number by what we call the "overcount" ratio (the total number of deaths in the United States divided by the total number of deaths in the United States, double counted). For total fatalities, these numbers are 35,453 and 49,906, resulting in a ratio of 0.7104. There are circumstances, however, in which our industry-wide overcount ratio might be systematically lower for manufacturers with higher market shares (and hence who are more likely to be involved in accidents with two or more of their cars). To account for this potential bias, we have in the Appendix recalculated the estimates in this Article using, as an alternative, manufacturer-specific overcount ratios. See Appendix at Table 1A.

230 "Fatalities over Median" is calculated by multiplying the difference between each manufacturer's fatality rate and the median fatality rate by the number of cars that the manufacturer has on the road. For those manufacturers whose difference is positive, these fatality numbers are then summed by year and averaged over twelve years. "Proportion of Fatalities over Median" represents the fraction of fatalities that would be saved if the fatality rate for manufacturers with a fatality rate over median were brought down to the median. "Yearly Cost of Fatalities over Median" is calculated by multiplying the number of "Fatalities over Median" by the EPA's estimate of the value of a statistical life—$7.4 million, in 2006 dollars. National Center for Environmental Economics, *Frequently Asked Questions on Mortality Risk Valuation* (EPA), archived at http://perma.cc/6QQX-VQEV. Both the "Fatalities over Median" and the costs are deflated by the number of single-counted fatalities divided by the number of double-counted fatalities of each type.

These saved lives, valued at the EPA's estimate of the value of a life of $7.4 million in 2006 dollars,[231] would represent an avoided cost of nearly $13 billion. Many of these lost lives come from people who were not riding in the above-median manufacturers' vehicle. These fatalities are literally, as well as figuratively, not well internalized. Table 2 calculates that there would have been 920 fewer external fatalities and that improving laggard fatality rates might have avoided 7 percent of all external fatalities, producing $7 billion in savings.

How concretely might a CAFE-like system be applied to internalize these costs of above-median fatality risks? The Appendix reports estimates of the one-time, per-vehicle penalties that might be imposed on nineteen manufacturers if they were held responsible for their above-median fatalities. We estimate that Mitsubishi cars are so dangerous that the present value of costs associated with above-median total fatalities is on the order of $4,600 per vehicle. Six other manufacturers (Land Rover, Kia, Pontiac, GMC, Isuzu, and Chevrolet) have estimated per-vehicle charges of more than $1,500.[232] The threat of imposing potentially crippling fines on these manufacturers would give them strong incentives to bring their fatality rates below (or at least substantially closer to) the industry median rate.[233] Those lagging manufacturers that failed to improve would, by raising their prices, indirectly improve safety by shifting consumers toward the below-median producers.

Alternatively, if one takes the view that manufacturers already have sufficient incentives to protect the drivers and passengers inside their own cars, then one might instead focus on estimates of per-vehicle charges associated with above-median external fatalities. Land Rover's excess external fatalities are associated with more than $2,500 of per-vehicle costs. Four other manufacturers (in descending order: GMC, Mitsubishi, Dodge, and Ford) are estimated to have costs associated with above-median external fatalities of more than $1,000 per vehicle.[234] It is harder to assert that these manufacturers fully internalize the

231 Id.

232 See Appendix at Table 1A.

233 The cross-elasticities of demand are high in some cases, especially with regard to cars in the same class. See *Demand for Cars and Their Attributes: Final Report* *xv–xviii (Economics for the Environment Consultancy, Jan 2008), archived at http://perma.cc/Y3VJ-JBKL. As a result, a manufacturer who attempted to pass along these substantial penalties would face dramatically restricted demand.

234 See Appendix at Table 1A.

costs associated with these elevated risks of external fatalities. Moreover, there are certain design strategies (beginning with reducing the weights of their cars) that are known to make cars less "aggressive" (that is, less dangerous to people outside the car).[235]

Our Appendix shows that some manufacturers have above-median total costs but not above-median external costs (for example, Plymouth and Oldsmobile), and vice versa (for example, Lincoln).[236] But we find particularly troubling the five manufacturers whose external costs exceed their total-cost estimates by more than $100 per vehicle. In descending order, these manufacturers are Dodge, Jeep, Ford, GMC, and Infiniti. For example, we estimate that for Dodge, the costs from above-median external deaths is $1,511 while the costs from above-median total deaths is only $423. This inversion of costs associated with total and external fatalities occurs because Dodge cars are substantially below median with regard to internal-fatality risks. The policy concern is that Dodge may be designing or promoting its cars in a way that makes them safer to their customers at the expense of outsiders. We estimate that for every internal life that Dodge saves by designing or promoting cars to bring the internal fatality rate below median, there are 2.2 above-median external lives lost. This creates the possibility that if Dodge modified its design to be less aggressive,[237] it might be able to produce a net reduction in total fatalities by trading off external for internal fatalities.

The final two columns in Table 1A of the Appendix also report the per-vehicle costs for above-median fatalities, but after accounting for differences in miles driven by cars made by different manufacturers. A manufacturer might be above median in fatalities per registered vehicle not because of an inferior manufacturer design but merely because the manufacturer's cars were driven for disproportionately more miles per year than the median car. The final columns account for differences in

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235 Jon S. Vernick, Gregory J. Tung, and Jonathan N. Kromm, *Interventions to Reduce Risks Associated with Vehicle Incompatibility*, 34 Epidemiologic Rev 57, 57–58 (2012).

236 See Appendix at Table 1A.

237 The fatality literature defines "aggressivity" as a vehicle's propensity to injure or kill someone in another vehicle. Vernick, Tung, and Kromm, 34 Epidemiologic Rev at 57 (cited in note 235). It is perverse that Dodge and other manufacturers market their cars as having aggressive exterior designs. See, for example, *Introducing the 2013 Dodge Lineup* (MOPAR News), archived at http://perma.cc/9LKT-9LYW ("[T]he Dodge Avenger takes an aggressive stance that's impossible to ignore.").

miles driven by manufacturer and report the reestimated implied costs per vehicle that would be charged under an innovation-stick regime.[238] While there are some substantial variations in the two methods of estimating per-vehicle costs, the larger picture is that controlling for the differences in the miles driven does not eliminate or even substantially change the order of the above-median manufacturers.[239]

Again, we emphasize that many caveats are in order. While the average number of miles driven by cars made by each manufacturer is controlled for, other unobserved characteristics of vehicle drivers that are correlated with high accident rates—like drivers being drunk or being teenage males—are not. The locations of the cars in certain states or regions will also affect accident rates. We take on many of these additional effects in the Appendix and argue that they do not materially alter our results. The purpose of this initial empirical exercise is to show that the project of bringing the safety of lagging manufacturers' cars in line with the fatality rates already achievable by below-median or median peers has the potential to produce first-order benefits to public safety.

B. Yardstick Penalties for Above-Median States

Among the caveats to the foregoing analysis is the possibility that certain manufacturers may disproportionately sell cars in areas that have different likelihoods of fatal accidents occurring.[240] If any geographic accident disparities were beyond the

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238 Estimates for miles driven per year are calculated using the NHTS's data on odometer readings and months since purchase. See Federal Highway Administration, *Introduction to the 2009 NHTS* (Department of Transportation), archived at http://perma.cc/V8UF-PVN2 (noting that the 2009 NHTS data update the 2001 NHTS data); Federal Highway Administration, *2009 National Household Travel Survey: User's Guide* *1-4 (Department of Transportation, Oct 2011), archived at http://perma.cc/3398-4WJA (stating that the purpose of the survey was to provide a national inventory of daily travel). Dividing the odometer reading by the number of months since the vehicle was purchased and multiplying by twelve gives a credible number of miles driven per year. Fatality rates are adjusted by calculating a fatality rate per car-mile, determining above- and below-median rates. By multiplying that number by the average number of miles driven, we return to a fatality-rate-per-vehicle metric.

239 Controlling for differences in the average manufacturer miles driven impacts the size of the implied penalties. The total-fatality penalty for Mitsubishi falls from $4,595 to $3,895, due to the tendency of Mitsubishi drivers to drive more miles per year than the average driver (approximately 12,500 versus 11,700, respectively). The Oldsmobile total-fatality penalty increased from $4 to $846 due to its drivers' below-average miles driven (10,200).

240 See generally Michael Sivak, *Road Safety in the Individual U.S. States: Current Status and Recent Changes* (University of Michigan Transportation Research Institute,

control of the manufacturer, imposing yardstick penalties would be inefficient and inequitable because the foregoing comparison to the national median would be an inappropriate yardstick. Table 3 shows that, even after controlling for regional differences in accident rates, the basic lesson of the foregoing analysis changes very little. For the manufacturer median analysis, the seventh column, entitled "Regionally Adjusted Yearly Cost," reports that the regional adjustments only modestly impact estimates for "Yearly Cost of Fatalities over Median" (reported in the sixth column below). For example, after adjusting for regional differences in manufacturer sales,[241] the above-median cost of total fatalities drops from \$12.9 billion to \$12.6 billion, while the above-median cost of external fatalities increases from \$7.0 billion to \$7.1 billion.

July 2014), archived at http://perma.cc/FM5Y-CWJ9 (providing evidence of the importance of geography to automobile fatalities).

241 To control for regional variation in fatality rates and manufacturer variation in vehicle location, we divide the country into four regions consistent with the US Census Bureau's delineation of regions. See generally *Census Regions and Divisions of the United States* (Census Bureau), archived at http://perma.cc/29E7-78SQ. Using the fatality data and the Department of Transportation's state-by-state registration data, we determine how much above or below the weighted-mean fatality rate each region is in each year, deriving the weight from the region's proportion of national registrations. Then, using the National Personal Transportation Survey data, we determine the distribution of vehicles by manufacturer across the four regions. The 2001 and 2009 vehicle distributions are averaged to compute each manufacturer's distribution for all years, which we assume does not change. Using these two pieces of information, we can calculate an adjusted rate (fatalities per 100,000 registered vehicles) for each manufacturer using the following formula:

$$(\text{adjusted rate})_{iy} = (\text{unadjusted rate})_{iy} - \Sigma\ (\text{share}_{ir} * \text{adjustment}_{iyr})$$

in which *i* indexes manufacturer, *y* year, and *r* region; *share* is the proportion of that car manufacturer in that region; and *adjustment* is the difference between each region's fatality rate and the national weighted mean. We subtract rather than add in order to adjust manufacturer rates down if a manufacturer's cars are more prevalent in high-fatality regions.

TABLE 3. ABOVE-MEDIAN FATALITY ANALYSIS

Manufacturer Median Analysis

	Std Dev / Mean	Skew	Fatalities over Median	Proportion of Fatalities over Median (%)	Yearly Cost of Fatalities over Median ($ billion)	Regionally Adjusted Yearly Cost ($ billion)
Total Fatalities	0.27	−0.09	1690	4.8	12.9	12.6
External Fatalities	0.31	0.08	920	7.1	7.0	7.1
Pedestrian External Fatalities	0.32	−0.48	88	3.9	0.7	0.7

State Median Analysis

	Std Dev / Mean	Skew	Fatalities over Median	Proportion of Fatalities over Median (%)	Yearly Cost of Fatalities over Median ($ billion)
Total Fatalities	0.38	1.11	8346	20.9	63.4
External Fatalities	0.39	0.77	3541	19.2	26.9
Pedestrian External Fatalities	0.42	0.73	1061	15.1	8.1

But the concern about local differences in accident rates raises the deeper question whether a CAFE standard might be applied to states themselves instead of (or as well as) to manufacturers. A state-centered system of yardstick penalties would charge states a penalty if they produced higher fatality rates than the (registration-weighted) median rate found in other states. The penalty would correspond to the losses associated with just those above-median fatalities in the state.

The right-hand columns of Table 3, building on estimates presented in the Appendix, compare the differences between an above-median manufacturer analysis and an above-median state analysis. While moving above-median manufacturers to the median total-fatality rate would have saved 4.8 percent more lives, Table 3 shows that moving above-median states to the median would have saved a whopping 20.9 percent of vehicular fatalities.[242] Similarly, the table reports that while above-manufacturer-median external fatalities represent 7.1 percent of all external fatalities, 19.2 percent of external fatalities come from above-state-median external fatalities. The substantial proportion of above-state-median deaths raises the possibility that from a public health perspective, there may be greater gains in changing the behavior of lagging states than in changing the behavior of lagging manufacturers.

Figures 4 and 5 show that particular states have, over time, been persistently above median with regard to both their total- and external-fatality rates.[243] Thus, Figure 4 shows that Mississippi's total-fatality rate has been not just above median but massively above median. Figure 2 shows that Mitsubishi was consistently above the manufacturer median for total fatalities, but Mitsubishi's rate averaged only 34 percent higher. In contrast, Mississippi's rate exceeded the median state rate by 187 percent.

242 Table 3 also suggests the reason why the proportion of above-state-median fatalities is so much larger than the proportion of above-manufacturer-median fatalities. The distribution of fatality rates across states is more variable and displays more upward skew than the distribution of fatality rates across manufacturers. For example, the manufacturer-level total-fatality-rate distribution exhibits a very slight downward skew (−0.09), while the state-level total-fatality-rate distribution exhibits a substantial upward skew (1.11). These distributional differences mean that the fatality rate conditional on having an above-average fatality rate is higher for states than for manufacturers.

243 The results of these tables are consistent with the analysis in Sivak, *Road Safety in the Individual U.S. States* at *i (cited in note 240):

> [T]he *fatality rate per distance driven* varies greatly. In 2012, the lowest fatality rates per 1 billion miles were in the District of Columbia (4.20), Massachusetts (6.24), and Minnesota (6.93). The highest rates were in West Virginia (17.63), South Carolina (17.60), and Montana (17.25). Similarly, the percentage change in this rate between 2005 and 2012 exhibited a wide range. On one extreme were the District of Columbia (−67.5%), Nevada (−48.0%), and Idaho (−39.0%). On the other extreme were Vermont (+12.7%), North Dakota (+3.8%), and Maine (+2.0%).

FIGURE 4. ABOVE-MEDIAN TOTAL FATALITIES BY STATE

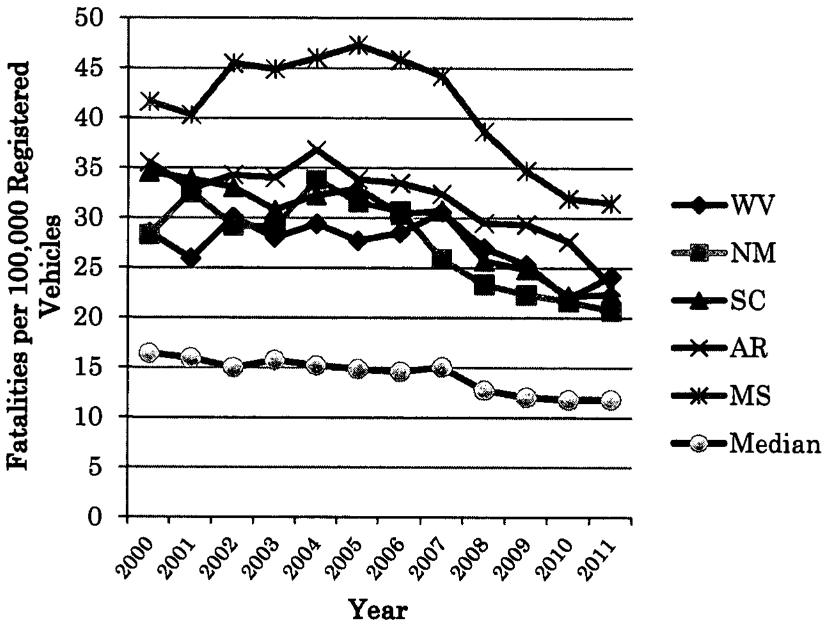

Figure 5 displays a similar story with regard to external fatalities. While the median rate of external fatalities fell by 42 percent from 8.4 per 100,000 population in 2000 to 4.9 per 100,000 population in 2011, many states expose their citizens to a hazard per registered car that is more than twice as high. The Appendix estimates the number of above-state-median fatalities and the associated per-vehicle penalties that would need to be imposed on states to fully internalize the costs associated with these above-median fatalities.[244]

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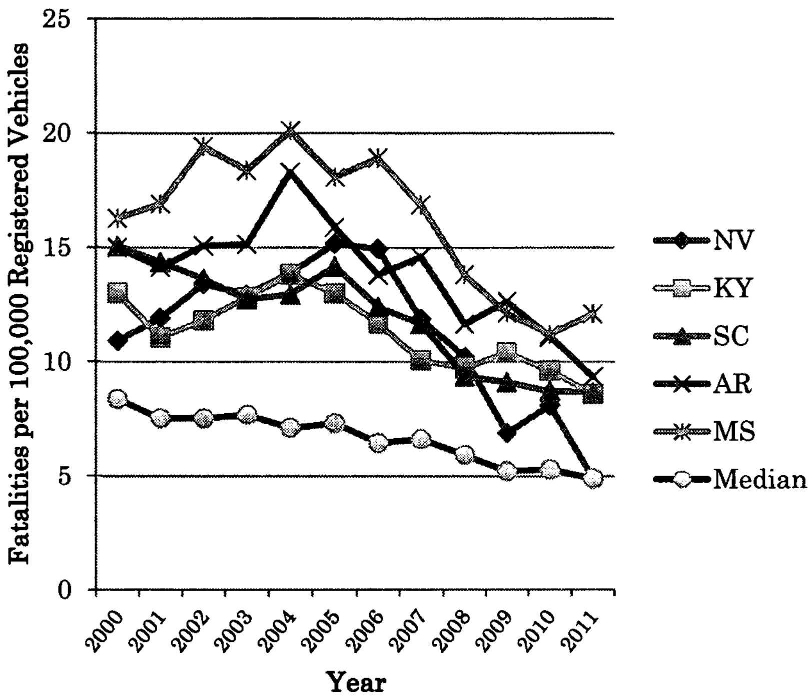
244 See Appendix at Table 1A.

FIGURE 5. ABOVE-STATE-MEDIAN EXTERNAL FATALITIES BY STATE



The upward skew of the state total-fatality distribution has a grim impact on our penalty estimates. Mississippi automobiles average 26.77 more deaths per 100,000 registered vehicles than the state median rate of 14.27 fatalities. If we value lives at the $7.4 million EPA-standard valuations, these above-state-median deaths in Mississippi represent a per-vehicle cost of more than $15,000. (In contrast, the worst above-manufacturer-median per-vehicle costs were only about $4,600.) If Mississippi were forced to pay a CAFE-like penalty (for example, in terms of lost federal funding) for these above-median fatalities, the annual penalty would amount to a crippling annual fee of $4.1 billion, which would equal nearly 80 percent of the state's current general fund appropriations.[245] If we instead limited our concern to

[245] See *State of Mississippi Budget: Fiscal Year 2014* *3 (State of Mississippi Joint Legislative Budget Committee, June 28, 2013), archived at http://perma.cc/C463-PZKA.

the above-median external fatalities, the annual penalty would be on the order of $1.45 billion.[246]

Taking into account state differences in miles driven reduces the implied per-vehicle penalty of states like Mississippi from $15,710 to $13,127 because Mississippi vehicles tend to be driven more miles per year than the average vehicle in the United States (14,200 versus 11,400 miles per year, respectively).[247] But the overall lesson is one of continuity: adjusting the innovation sticks to take account of miles driven does not dramatically change the identity or size of the penalties that would internalize the social costs of above-median fatality rates.

Whether it is appropriate to control for differences in miles driven turns on whether manufacturers or states should be incentivized to take account of how much their cars are driven. We imagine that there are actions that either states or manufacturers might take to reduce the miles driven.[248] But it is not clear that these actions are cost beneficial. For example, the states with the highest average miles driven per registered car per year are more rural. Forcing these states to internalize more of the costs of driving may inequitably and inefficiently disrupt their economies. Accordingly, we might wish to allow controls for differences in miles driven.

In contrast, we do not think that it is appropriate to control for all intervening variables that might impact the fatality rate. Accidents and fatalities are attributable to driver and environmental factors as well as to issues of manufacturer design. A manufacturer who disproportionately sells to teenage drivers or to drivers who drive while drunk is likely to have higher fatalities than a manufacturer with an equally safe design who disproportionately sells to safer drivers. In the Appendix, we show that teenage-male driving and driving under the influence of drugs or alcohol are likely causes of some of our above-median

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246 The rationale for focusing on external fatalities is, however, more problematic when analyzing the above-median state fatalities. A state's voters already, in theory, internalize the risks of both internal and external fatalities. The duly elected state officials may already have sufficient incentives to respond to automobile fatalities occurring in their jurisdiction.

247 The difference between the miles driven for the average vehicle (11,400) and the number mentioned in note 239 (11,700) is due to the error introduced in the sampling methodology of the NHTS. The discrepancy is around 3 percent. *2009 National Household Travel Survey* at *7-1 to -2 (cited in note 238).

248 For example, either manufacturers or states might offer drivers a rebate if they agree to higher gasoline taxes. See generally Ian Ayres and Barry Nalebuff, *Why Not? A Voluntary Gas Tax* (Forbes, Mar 16, 2009), archived at http://perma.cc/LB8X-PXDQ.

results.[249] Nonetheless, we believe that it is likely appropriate to hold manufacturers and states financially responsible for these above-median deaths because both manufacturers and states can plausibly take cost-effective actions to reduce the fatality risks of these disproportionately dangerous driver types. For example, manufacturers might affect teenage accident rates by facilitating the use of GPS monitoring to keep insurance companies and parents aware of reckless teenagers' driving patterns.[250] Manufacturers could affect drunk driving accident rates by following Ford's lead and including automated audible warnings that go off inside the cars when drivers are caught drifting out of their lanes.[251] Existing driver-assist technologies available from Mercedes and a number of other manufacturers use a forward-looking radar to detect imminent collision and automatically brake the car (utilizing the full distance to the object to reduce the likelihood of being hit from behind) while simultaneously flashing brake lights, tightening seat belts, adjusting head rests, closing the windows and the roof, and raising the roll bar.[252]

State action can also directly affect both teenage-male and drunk driving accident rates. Graduated driver's license requirements for teens could be made more stringent in many states.[253] The requirement that teens not drive after 8:00 p.m., for example, has been found to lower teenage-fatality rates by 20 percent.[254] A wide variety of policy interventions are available to states that wish to lower drunk driving accident rates—including enforcement of seat belt laws, lower speed limits, sobriety checkpoints, and speed cameras.[255] Roadway improvements—such as rumble strips both on the edges and in the middle of roads, roadway lighting, and guardrail improvements—

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249 See Appendix at Part III.A.1.

250 See Kathleen Doheny, *Car Tracking Devices for Teen Drivers: Monitoring Can Help, but It Doesn't Replace Communication* (Edmunds.com, May 23, 2013), archived at http://perma.cc/U35A-3QSG.

251 See Paul Stenquist, *New Ford Fusion Will Warn Drivers Who Drift* (NY Times, Dec 29, 2011), archived at http://perma.cc/Y4NC-VXEW.

252 See, for example, A. Goodwin, et al, *Countermeasures That Work: A Highway Safety Countermeasures Guide for State Highway Safety Offices* *5-22, 6-14 (NHTSA, 2013), archived at http://perma.cc/882K-LREH.

253 The Governors Highway Safety Association keeps a list of state-by-state teenage-driver requirements. *Graduated Diver Licensing (GDL) Laws* (Governors Highway Safety Association, Feb 2015), archived at http://perma.cc/N7KX-VAAH.

254 See Anne T. McCartt, et al, *Graduated Licensing Laws and Fatal Crashes of Teenage Drivers: A National Study*, 11 Traffic Injury Prevention 240, 246 (2010).

255 See, for example, Goodwin, et al, *Countermeasures That Work* at *1-19, 3-12, 6-14, 8-24 (cited in note 252).

are another possibility. States could also lower the legal blood alcohol concentration (BAC) threshold below 0.08 (as studies have shown that impairment occurs at a BAC as low as 0.01)[256] and require the use of ignition "interlock" Breathalyzer systems for driving-under-the-influence (DUI) offenders.[257] DUI enforcement could become more high profile, or states could take away drivers' licenses or cars if drivers were caught driving drunk.[258] Given the wide range of plausibly cost-effective interventions that could be undertaken by both manufacturers and states, it is inappropriate to control for differences in DUI when calculating the size of innovation-laggard penalties.

The plausible ability to effectively react to incentives is a necessary but not sufficient basis for imposing even partial penalties. We have not developed a theoretical account here explaining *why* we should reduce car fatalities. Rather, we have loosely assumed a welfarist approach in the style and manner of our reasoning, but we have not done more than that in part because we believe that reductions in such fatalities are likely to be desirable from many different normative perspectives. However, different value perspectives may also generate arguments that should be addressed before adopting such penalties. From a welfarist perspective, for example, there are unaccounted-for benefits of fast, reckless, and even inebriated driving.[259] A liberal or rights-based perspective might generate additional objections, such as concerns that pressures on manufacturers would lead to technologies with an unacceptable impact on privacy or autonomy or that

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256 See *Safety Report: Reaching Zero; Actions to Eliminate Alcohol-Impaired Driving* *22–24 (National Transportation Safety Board, May 14, 2013), archived at http://perma.cc/7N72-X8RH (providing that driving-related performance is degraded at BAC levels as low as 0.01 and recommending a reduction of the BAC limit).

257 See id at *28 ("In 2011, more than 1.2 million arrests were made for [DUIs] . . . yet, as of 2012, fewer than 280,000 interlocks were in use in the United States.").

258 Professor Miguel F.P. de Figueiredo has found that the punishments for DUIs did not affect the probability of recidivism, but that license suspensions (during the suspension period) and interlock devices did. Miguel F.P. de Figueiredo, *Throw Away the Jail or Throw Away the Key? The Effect of Punishment on Recidivism and Social Cost* *42–59 (unpublished manuscript, June 21, 2014), archived at http://perma.cc/EQ6R-Q7CB.

259 See, for example, Carolina Pinto Pereira Barbosa, *Economic Evaluation of Alcohol Treatments: Linking Drinking Patterns, Alcohol Consequences and Cost Effectiveness of Alcohol Treatments* *58–59 (unpublished PhD dissertation, University of York, Feb 2010), archived at http://perma.cc/WNR4-5SHT (explaining that welfarists believe that individuals are the best judges of their own welfare and that the social consequences of alcohol abuse should be estimated only as net social consequences, as drinkers' private consequences and associated costs and benefits are irrelevant to the interests of others).

pressures on states would lead to problematic surveillance.[260] From a welfarist, liberal, or rights-based approach—among others—one might also question whether it is appropriate for the federal government to shift the incentives of states in the ways we suggest here. The politicians of Mississippi and other laggard states already have some incentives (or, put in a more deontic frame, some responsibility) to protect the citizens of their states both inside and outside of automobiles. Before imposing penalties on states, we should have a better account of why local politics do not adequately address the problem.

A few further caveats are in order. Before imposing such a system on the states, we might also want a closer study of the reasons for the disparities.[261] For example, poverty may be a deeper driver of the higher fatality risk in laggard states. In the public health literature, poverty puts people at systematically higher risks for a variety of bad outcomes—including alcoholism and accidents.[262] States with more-impoverished drivers may have fewer cost-effective actions to mitigate their above-median fatality rates. Before imposing such a system on manufacturers, we might want to consider the extent to which manufacturer penalties may merely cause a reshuffling of high-risk drivers without improving overall safety.

At a minimum, our empirics are sufficient proof to warrant further consideration. We have shown that particular manufacturers and particular states persistently lag behind the median levels of safety achieved by their peers and that penalties that would move these laggards to the median might save thousands of lives per year. Finally, our example helps to illustrate the

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260 See Roger C. Cramton, *Driver Behavior and Legal Sanctions: A Study of Deterrence*, 67 Mich L Rev 421, 421–22 (1969).

261 Two possible reasons that have occurred to us, but that are not explored in this analysis, include differences in the number of (or distance to) high-level trauma units in different states and differences in the average age of the fleet. Closer analysis of these drivers might be illuminating. Controlling for these differences would be appropriate only if we assumed that these factors cannot or should not be influenced by the stick (or carrot). See text accompanying note 258.

262 See generally, for example, Elisa R. Braver, *Race, Hispanic Origin, and Socioeconomic Status in Relation to Motor Vehicle Occupant Death Rates and Risk Factors among Adults*, 35 Accident Analysis & Prevention 295 (2003) (finding that fatal-accident victims from lower socioeconomic strata were more likely to have higher BACs than those of higher socioeconomic status). If poverty were a main factor, then sticks that further impoverished laggard states might just exacerbate the issue. In the language we develop in the text accompanying this note, we would have more of an undercompensation than overcompensation problem, and carrots might in this case be more appropriate than sticks.

potential power of a sticks-based approach to innovation as well as some of the complexities associated with the design of innovation sticks. While these complexities should be taken seriously, feedback effects can help refine such sticks over time. Our empirics also help to vividly show the high costs of inaction in an area in which innovation can plausibly have very beneficial effects but is not well incentivized by traditional carrots.

CONCLUSION

There may be no more hoary expression than the one we began with: necessity is the mother of invention. It is striking, therefore, how absent this trope is from scholarly thinking about innovation. No one says that "reward is the parent of invention," but innovation policy is almost exclusively about what kind of legal carrot would best promote invention.

Recognizing this absence leads us to ask whether stick incentives or carrot-and-stick regimes might ever be normatively attractive. It also allows us to ask whether such regimes have ever existed. We have provided examples here of innovation sticks in use and have also provided an argument as to why, in certain circumstances, they are appropriate. Further, we have offered strategies, such as the use of yardsticks, that can increase the plausibility of innovation sticks. We have even provided heuristic empirics on why and how yardstick penalties might be applied to laggard states and automobile manufacturers in order to encourage each to innovate to reduce car fatalities. Enlightened policymaking will never embrace Rumpelstiltskin threats—"Figure out how to spin straw into gold or we'll have your head off!"[263] But this Article has shown that policymakers at times should use—and in fact have already used—smart systems of potential penalties to shape innovation incentives.

To see the value of innovation sticks, we must recognize three points that have not yet been fully appreciated in the IP literature. First, innovation comes in many modes, only some of which are well compensated by conventional IPRs and only some of which generate goods that are "public goods" in the classic sense of the term. Second, it may be difficult, as a policymaker, to tell whether innovation or merely adoption of an innovation is needed. Mechanisms that are agnostic as to the mode of innovation, or even as to whether results are reached with innovation

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263 See *Grimm's Complete Fairytales* 235–38 (Barnes & Noble 1993).

or rote adoption, can therefore also be valuable. These first two points advance our appreciation not only of sticks but also of nontraditional carrots. A third point is critical to understanding the possible value of sticks: when setting innovation policy, overcompensation—not just undercompensation—is a possible risk. When innovation is possible without major free rider problems, sticks have advantages over nontraditional carrots and may make substantial efficiency gains possible.

While most academics in this field think of themselves as intellectual property scholars, our insights here pose a new question: Should there also be a category of "intellectual antiproperty"?[264] If IP is a conditional asset that one acquires by being creative, intellectual antiproperty would be a conditional liability that one could avoid only by being creative.[265] And antiproperty will sometimes be a more efficient means to induce innovation than property itself.

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[264] For a different usage of the term "antiproperty," see Abraham Bell and Gideon Parchomovsky, *Of Property and Antiproperty*, 102 Mich L Rev 1, 5 (2003) ("Antiproperty rights are veto rights over the use of an asset that are granted to a large number of private actors.").

[265] Put in option terms, intellectual property regimes grant potential innovators call options, while intellectual antiproperty regimes would grant potential innovators something more analogous to a put option. See Ian Ayres, *Optional Law: The Structure of Legal Entitlements* 45 (Chicago 2005) (discussing the characteristics of option value generally). Or, alternatively, we might consider this contingent liability as a form of "intellectual tort law." See Wendy J. Gordon, *Copyright as Tort Law's Mirror Image: "Harms," "Benefits," and the Uses and Limits of Analogy*, 34 McGeorge L Rev 533, 535 (2003) ("In copyright law, 'carrots' are given to plaintiffs to make them produce more creative works. In tort law, 'sticks' are imposed on defendants to make them engage less in destructive behavior. In this way, torts and copyright mirror each other, operating in ways that are parallel but reversed.").